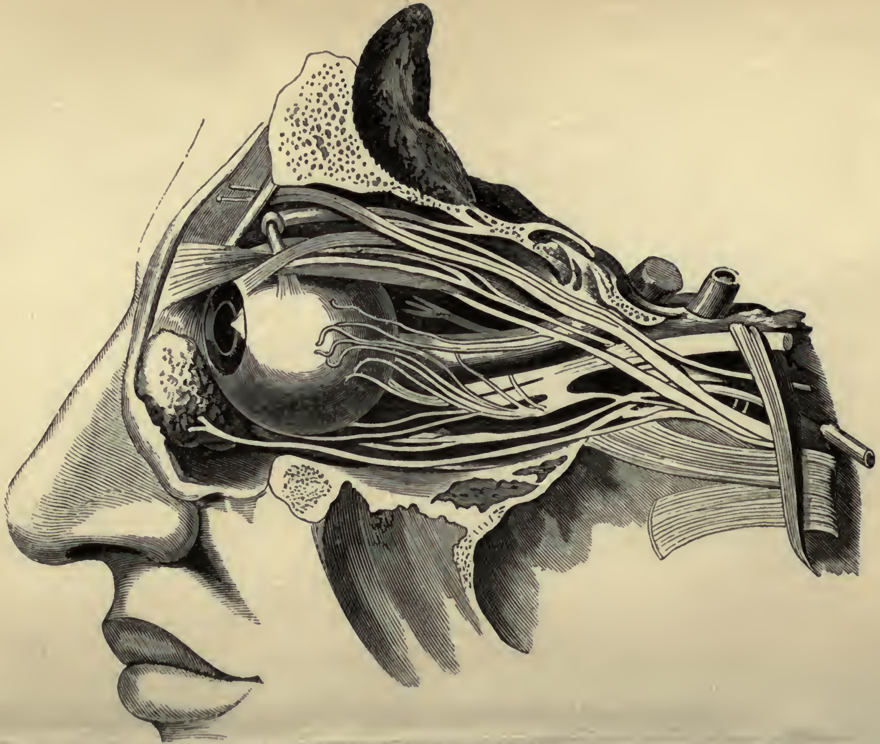
UNIVERSITY OF TORONTO
3 1761 01711971 0

Handle with
EXTREME CARE
This volume is
BRITTLE
and cannot be repaired
Photocopy only if necessary
GERSTEIN SCIENCE
INFORMATION CENTRE

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/philosophyofeyeb00walkuoft



d 4"

THE
PHILOSOPHY OF THE EYE;

BEING A FAMILIAR

EXPOSITION OF ITS MECHANISM,

AND OF THE

PHENOMENA OF VISION,

WITH A VIEW TO THE EVIDENCE OF DESIGN.

BY

JOHN WALKER,

AUTHOR OF "THE PRINCIPLES OF OPHTHALMIC SURGERY," LECTURER ON
THE EYE IN THE MANCHESTER ROYAL SCHOOL OF ANATOMY AND
MEDICINE, AND ONE OF THE SURGICAL OFFICERS OF THE
MANCHESTER EYE INSTITUTION, &C.

With numerous Illustrations.

LONDON:
CHARLES KNIGHT & CO., LUDGATE STREET;
AND GEORGE SIMS, MANCHESTER.

MDCCCXXXVII.

"There is that in what we do understand of the formation of the EYE so similar, and yet so infinitely superior, to a product of human ingenuity,—such thought, such care, such refinement, such advantage taken of the properties of natural agents used as mere instruments for accomplishing a given end, as force upon us a conviction of deliberate choice and premeditated design, more strongly, perhaps, than any single contrivance to be found, whether in art or nature, and render its study an object of the deepest interest." —SIR JOHN HERSCHELL, *Encyclopædia Metropolitana.*

TO

JOHN WINDSOR, Esq., F.L.S.,
&c. &c.

IN TESTIMONY OF ESTEEM AND GRATITUDE

FOR

MANY FAVOURS CONFERRED,

THE

FOLLOWING PAGES ARE INSCRIBED

BY

THE AUTHOR.

LIBRARY
APR 4 19[illegible]
UNIVERSITY OF TORONTO

QP
.H75
W3

CONTENTS.

CHAPTER I.

Page

INTRODUCTORY Observations 1

CHAPTER II.

On Vision 8

CHAPTER III.

General view of the structure of the Eye—Its superior construction, as compared with optical instruments—The numerous instances of design it affords 25

CHAPTER IV.

Of the means by which images of objects are formed—The lenses of the Eye 48

CHAPTER V.

Of the refractive powers of artificial lenses and those of the Eye—Nature and properties of light 84

CHAPTER VI.

Of the tunics or coats of the Eye 107

CHAPTER VII.

Of the colouring matter of the Eye and its membrane, the choroid, &c. 121

CHAPTER VIII.

Of the Iris or septum of the Eye 139

CHAPTER IX.

Page

Of the means by which information of the images is conveyed to the brain—Retina and Optic Nerve 188

CHAPTER X.

Of the moving powers of the Eye—Its muscles and their nerves 204

CHAPTER XI.

Of the defences of the Eye—The orbit—The eye-lids—The lacrymal apparatus—The Eye-brows 240

CHAPTER XII.

On the sensibility of the Eye 263

Conclusion 290

INDEX 295

PREFACE.

Various successful attempts have been made, during the last few years, to popularize a knowledge of the structure and functions of the animal body, particularly by Sir Charles Bell, Dr. Roget, and Dr. Southwood Smith.

Among the many portions of the subject that have attracted the notice of these eminent men, that of all others the most interesting—the Eye—can scarcely be regarded as having met with the degree of attention to which its admitted claims would seem to have entitled it. Hitherto there has been no separate treatise to which the general reader could refer for an ample and satisfactory account of this organ; although surely, if there be any one in particular that deserves to be isolated and considered apart from the other animal organs, it is that which contributes to vision, the noblest of the senses.

Every one is aware of the exquisite delicacy, and acknowledges the admirable construction, of the Eye; its excellence has been at all times proverbial; there are but few, however, who understand the real grounds upon which this excellence depends, and an attempt to elucidate these is perhaps deserving of notice.

But the Eye itself, wonderfully organized as it is, can only properly be regarded as the centre of a system of organs, all contributory to the perfection of the sense, and without almost any of which that sense would be either annihilated or materially impaired. Hence it has been considered necessary to treat, not of the Eye exclusively, but likewise of its various subsidiary organs.

It is the special object of the present undertaking, then, to supply the presumed want of a separate and familiar treatise on the mechanism and functions of the visual apparatus, including the Eye and its appendages.

The author has felt it impossible to perform the task which he had assigned to himself without frequent references to the evidence of design, so abundantly furnished by the Eye. However, he has scarcely allowed himself to do more than incidentally touch upon this most interesting topic,—a topic which has been so ably discussed, and indeed almost exhausted, by the learned and accomplished writers of the Bridgewater and other similar Treatises.

Nor is this work intended to form a complete system of the anatomy and physiology of the Eye; there being many points which could not properly be introduced into a production like the present. The reader desirous of prosecuting the subject, particularly the anatomy of this organ, is referred to the more voluminous publications of Zinn, Soemmerring, and Dalrymple, especially that of the last named author, which is the most complete and comprehensive work on this branch of science in the English language.

It may be thought, perhaps, that this treatise would have been more perfect had the author entered more extensively and minutely into the comparative anatomy of the organ, there being many circumstances in the formation and arrangement of the

Eyes of the more simple orders of beings that are of an interesting character; but it was his desire to adhere more especially to a description of the Eye of man, and of the higher orders of animals, so as to avoid rendering the subject too complicated, and therefore repulsive. If, by the course adopted, he shall have succeeded in giving a plain, intelligible, and somewhat interesting account of this beautiful portion of the animal fabric, his aim will have been accomplished.

The illustrations which accompany this volume will, it is presumed, tend materially to facilitate the acquirement of a knowledge of the subject; they have been derived chiefly from the before-mentioned authors, and from a few other scientific works.

The difficulties which surround the subject have been admitted by every competent writer; the author trusts, however, that he has not in vain attempted to reduce their number, and that this portion of physiology may be considered to have been somewhat advanced by his labours.

PHILOSOPHY OF THE EYE.

CHAPTER I.

Introductory Observations.

EVERY one who examines and attempts to treat of the interesting subject of vision finds himself compelled, involuntarily, to exclaim in terms of the highest admiration of the superior beauty and contrivance of its inimitable organ,—the eye.

Whether we take into consideration the brilliancy of structure so remarkable in that organ, the complication and rapidity of its movements, or its exquisite sensibility, we are equally astonished and delighted. We have said that it is the most beautiful of all the organs of the senses; it is, likewise, the most important, and therefore the most valued. All the other organs are necessary to the well-being of the individual, but there is none so essential as that of vision. It is emphatically the great inlet, the high road of knowledge. It is capable of imparting to the mind information, relative to objects so vast, that the other senses cannot grasp them, and of bodies so minute as to elude the most delicate and refined tact. It recognizes objects, whether placed in the immeasurable wilds of space, or at an hair's breadth distance. Possessing such powers, we perceive that it is with justice, the eye has been termed the window of the soul. Its importance is further apparent when we consider what a lengthened, tedious, and unintelligible account of an object we sometimes receive in words, which, if directed to the eye, either actually or by representation, would be instantly comprehended in all its bearings. Thus we shall often obtain more information concerning some objects at a single glance, occupying only an instant of time, than by a whole hour's description addressed to the mind through the ear.

It requires no argument to prove that the loss of so important a function, as that of vision, is one of the greatest of evils. The prince of English poets has given expression to his feelings in the most desponding and dolorous terms:—

> ———— " O why was sight
> To such a tender ball as the eye confined,
> So obvious, and so easy to be quenched;
> And not, as feeling, through all parts diffused,
> That she might look at will through every pore?"

And, again, in somewhat more subdued, but equally pathetic terms, he utters his sublime verse:—

———— "Not to me returns
Day, or the sweet approach of ev'n or morn;
Or sight of vernal bloom, or summer's rose;
Or flocks, or herds, or human face divine;
But cloud instead, and ever-during dark
Surrounds me, from the cheerful ways of men
Cut off, and for the book of knowledge fair
Presented with an universal blank."

Not only is it a great moral loss, but it is also a physical injury. Even where the external portion of the organ remains entire, such as was Milton's case,* the dull, inexpressive appearance of the eyes, cut off from all intercourse with the external world, is a sad blot in the "human face divine." How much greater is the deformity when the exterior of the organ becomes defaced, shrinks back into the orbit, or is totally destroyed!

---

* The actual condition of his eyes is thus graphically described:—

———— "These eyes, though clear
To outward view, of blemish, or of spot,
Bereft of light, their seeing have forgot;
Nor to their idle orbs doth sight appear
Of sun, or moon, or star throughout the year!
Or man, or woman!"

The resources of Nature are, however, wonderful and inexhaustible. When, from any cause, accident, disease, or original deficiency,—this portal of knowledge is sealed up, we find an increased activity of the other organs, particularly those of touch and hearing, which in some measure compensate for the absent sense. It is very certain, likewise, that individuals in this condition gradually become habituated to their fate, and are capable of enjoying a very considerable share of tranquillity. We have a striking proof of this in the instance of M. HUBER, the celebrated naturalist, and who might never have been celebrated but for his blindness. He lost his sight at the age of seventeen, having previously become attached to a young lady to whom he was afterwards married. He was wont to declare that he should be miserable were he to cease to be blind. "I should not know," said he, "to what extent a person in my situation could be beloved; besides, to me my wife is always young, fresh, and pretty, which is no light matter." If, therefore, persons who have once experienced the enormous advantages that attend the exercise of the faculty of vision can reconcile themselves to its deprivation, those who have been born blind, or who have lost their sight at so early an age that the mind was incapable of profiting by its existence, can hardly be supposed very much to regret the loss of an advantage which they never could appreciate.

Accordingly, we read of instances of blind individuals who have given proofs of the most astonishing intelligence, ingenuity, and address. Among the most remarkable of these is the celebrated living traveller Lieutenant Holman, who lost his sight at the age of twenty-seven. He informs us that the dread uncertainty which he experienced, before it was made known to him that he would be permanently blind, was infinitely more painful than the actual announcement of his future condition. He had early imbibed, or it may be that it was inherent in him, a thirst for exploring foreign lands; this was not diminished by the loss of vision; on the contrary, he continued his travels in all quarters of the globe. Curiously enough, he has endeavoured to make it appear to the world that he possesses advantages over those travellers who have the use of their eyes, most of whom he appears to regard as having eyes, and seeing not.

Another singular instance is that of Professor Saunderson; he lost both his eyes in infancy, and yet acquired such a knowledge of mathematics and natural philosophy, as to enable him to lecture on those branches of science in the University of Cambridge. His information was chiefly obtained by being read to; whilst the touch was the sense by which he procured all the rest of his knowledge. A very extraordinary anomaly, truly, that a man, blind from infancy, should be capable, nevertheless, of giving lectures, in a public college, on the laws of light!

Perhaps the strangest of all those of whom we have any account is John Metcalf. This person, who was blind from infancy, was remarkable in his boyhood for all kinds of daring feats, such as hunting, swimming, horse-racing, &c. He was afterwards made a surveyor of high-ways, in which capacity he built bridges and projected roads in the most mountainous district of England, the Peak of Derbyshire!

All this tends to show the wonderful elasticity of the human mind, which can reconcile itself in such an astonishing manner to the most adverse and distressing circumstances; for, after all, blindness cannot be regarded otherwise than as one of the greatest calamities to which humanity is subject.

since the majority of persons so situated are really in a most helpless and pitiable condition, a burden to themselves, and a source of intense and painful anxiety to their friends. And, accordingly, if we desire to place in the strongest point of view the importance of the visual organ in the animal economy, we need do nothing more than simply to refer to the state of those unfortunate individuals who are deprived of that inestimable possession.

CHAPTER II.

On Vision.

If the question be put to us, what is vision? we shall have some difficulty in giving a direct answer. By Swift it has been paradoxically defined *the art of seeing things that are invisible.* When we consider that it is a faculty which is brought into exercise in earliest infancy, it will be evident that the stages by which we first acquire it, and the impressions then made upon the unformed mind, all pass away, without leaving the slightest trace behind. It is, however, a faculty which requires exercise or training, in like manner as speech or hearing, and is certainly not acquired on the instant, is not intuitive, as many might be led to suppose.* Now, as we cannot refer back to our own impressions in infancy, and as the infant mind is utterly incapable, from the imperfection of its faculties, of making known its sensations, we should, without other means, probably not be able to arrive at a true conception of the nature of vision. Certain it is, that the most vague and incomprehensible notions have prevailed on this subject, and it is to the successful exertions and philosophic views of an English surgeon, the immortal Cheselden, that we owe the information which served to erect a suitable basis for a true theory of vision. This celebrated individual has left us the history of a boy who had been born blind, and on whom he performed an operation, which had the effect of enabling him to see. He tells us that "when he saw the light for the first time, he knew so little how to judge of distances, that he believed the objects which he saw 'touched his eyes' (and this was his expression), as the things which he felt touched his skin. . . . . . He did not know the form of any object; nor could he distinguish one object from another, however different their figure or size might be; when objects were shown to him which he had known formerly by the touch, he looked at them with attention, and observed them carefully, in order to know them again; but as he had too many objects to retain at once, he forgot the greater part of them, and when he first learned, as he said, to see and to know objects, he forgot a thousand for one that he recollected. It was two months before he discovered that pictures represented solid bodies; until that time he had considered them as planes and surfaces differently coloured, and diversified by a variety of shades; but when he began to conceive that these pictures represented solid bodies, in touching the canvass of a picture with his hand he expected to find in reality something solid upon it, and he was much astonished when, upon touching those parts which seemed round and unequal, he found them flat and smooth like the rest; he asked which was the sense that deceived him—the sight or the touch? There was shown to him a little portrait of his father which was in the case of his mother's watch; he said that he knew very well it was the resemblance of his father; but, he asked with great astonishment, how it was possible for so large a visage to be kept in so small a space, as that appeared to him as impossible as that a bushel could be contained in a pint."*

---

* Shakspeare has put this sentiment into the mouth of one of his characters, Glo'ster, in his reproof of an impostor, who pretended to have been restored to sight by a miracle.

"If thou hadst been born blind,
Thou might'st as well know all our names as thus
To name the several colours we do wear.
Sight may distinguish colours;
But *suddenly* to nominate them all,
It is *impossible.*"

The observations of Cheselden have since been confirmed by other testimony, but in none more fully and satisfactorily than in the following instance, recorded by an eminent living surgeon, Mr. WARDROP. This individual, a female of mature age and very intelligent, had been born blind, probably from cataracts; she had had operations performed on both eyes in her infancy, which were followed in the one by a closure of the pupil, and in the other the eye-ball had been totally destroyed. Her blindness was complete, "being able merely to distinguish a very light from a very dark room, but without having the power to perceive even the situation of the window through which the light entered; though in sunshine or in bright moonlight she knew the direction from whence the light emanated." In this condition Mr. Wardrop performed three different operations upon the remaining eye, after the last of which she became sensible of the presence of external objects, through the medium of this organ. Now, we might be led to suppose that a person thus situated, having existed in a state of darkness for nearly fifty years, with the light of heaven first streaming into her eye, would be in a delirium of joy, a state of mental intoxication: we might imagine that an individual thus circumstanced, on first beholding the infinite variety of objects by which we are surrounded, would be in a condition little short of ecstasy. When, however, we look into the actual facts, we are far from having this opinion confirmed. We are informed that on the second day after the successful operation, she was requested to examine a watch which had been shown to her the previous day, when she positively refused to do so, "saying, that the light was offensive to her eye, and that she felt very stupid, meaning that she was much confused by the visible world thus, for the first time, opened to her.

---

* Philosophical Transactions, 1728.

"On the sixth day she said that she saw better than she had done on any preceding day; 'but I cannot tell (said she) what I do see: I am quite stupid.' She seemed, indeed, bewildered, from not being able to combine the knowledge acquired by the senses of touch and of sight, and felt disappointed in not having the power of distinguishing at once by her eye objects which she could so readily distinguish from one another by feeling them. The next day, on examining with the eye the tea-cups and saucers, and being asked what they were, 'I don't know,' she replied; 'they look very queer to me; but I can tell what they are in a minute when I touch them.' So with an orange which was lying before her; she could make nothing of it until she actually touched it. When the experiment was made of giving her a silver pencil-case and a large key to examine with her hands, she discriminated and knew each distinctly; but when they were placed on the table, side by side, though she distinguished each with her eye, yet she could not tell which was the pencil-case and which was the key.

"In six weeks after the operation she returned home. At this period she had learned a great deal; she had acquired a pretty accurate notion of colours, but with regard to forms and distance she was still very ignorant. She had also great difficulty in directing her eye to an object; so that when she attempted to look at anything, she turned her head in various directions, until her eye caught the object of which it was in search. She still entertained, however, the same hope which she expressed soon after the operation, that when she got home her knowledge of external things would be more accurate and intelligible, and that when she came to look at those objects which had been so long familiar to her touch, the confusion which the multiplicity of external objects now caused would in a great measure subside."*

It is thus rendered apparent, that in order to see, we must possess something more than an organ of vision, or, in other words, that an uninstructed eye would be of no manner of use to us; that that organ requires as much training or educating, in order to distinguish visual objects, as the ear to discriminate sounds, or the mouth to articulate intelligible language; and that the former is almost as difficult and tedious a process, and requires nearly as much time and attention, as the latter.

There is a very striking analogy between learning to see objects around us, and the kindred art of discriminating between the various mystic signs, commonly called letters, which are used to represent those objects. Every one remembers the difficulty he experienced in retaining a recollection of the various symbolic representations employed in the alphabet. So that to the uninitiated eye the perusal of Hebrew, Greek, or even the letters by which the mother tongue is set forth, conveys no more information than the forms of natural objects did to the individuals we have just referred to. They each require frequent repetition, long practice, and careful attention, before the mind is capable of recognizing them, which she does not until she has had opportunities of becoming quite familiar with them.

---

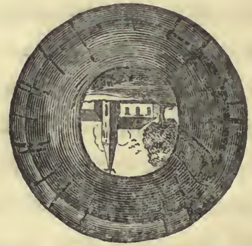
* Philosophical Transactions, 1826.

In the individuals alluded to we perceive the difficulty they experience, not only in acquiring information through the eye, but likewise of associating the impressions conveyed by that organ with those acquired through the sense of touch. That such an agreement between the different senses takes place is very certain. We see its gradual development in the infant. The first information is undoubtedly obtained through the touch, and the first instrument of touch is the mouth; afterwards the hand is called into the aid of the mouth; and, finally, the eye is associated with the others, the whole process being effected in that slow and gradual manner as to be almost imperceptible.

It is, unquestionably, this association between the senses that corrects the errors which we should otherwise be continually falling into with regard to the most common and familiar objects. Thus we could not ascertain, simply by the eye, the actual size or position of any object whatever, the information received by this organ being compared with and corrected by other information obtained through the sense of touch, and the result of the whole being a pretty correct knowledge of the object desired to be known. But a person, unaccustomed to this kind of observation, can scarcely ever guess, with anything like precision, of the real size or distance of almost any object in nature.

It may here be said, we perceive clearly enough that the eye is necessary to vision; but in what manner does the possession of an eye enable us to see, or, in other words, to render us conscious of the colour, figure, and position of objects which are presented to that organ? We seem to understand, without much difficulty, that when we take any object in the hand, and submit it to examination, we obtain a knowledge of many of its properties, such as its weight, form, and size, although this is equally a matter of experience. In this case, however, the object is brought into actual contact with the surface of the body; but, with respect to the eye, it is different,—there is no such contact. In order to see any object, it is essential that it be placed at a certain distance from the eye. How then do we see objects which are removed to a distance from us, so as to be out of the reach of contact, to be in fact placed, as some visible objects are, millions of miles from us? How are we to become acquainted with them, when these objects, so far from touching our eyes, are actually and of necessity removed from them? Now, it certainly cannot be effected by touch or contact: no, it is something very different; for instead of the actual object itself, the eye is presented with a picture, an image of the object. Yes, a beautiful, correct, and most perfect picture of the object is painted in the bottom of the eye, by means of the light proceeding from the object. Thus any one who is engaged in contemplating some charming landscape, or in admiring some beloved countenance, has literally portrayed the most accurate representation of the delightful object on the expanded nerve of the eye; or the traveller, as he moves along the road, has, successively, each portion of the scenery by which he is surrounded—the trees, fields, rocks, water-falls, all of the most diminutive size—transferred in all its glowing tints to the minute canvass prepared for its reception;

thus forming a natural and living panorama, more refined, more delicate, and more correct, than any effort of art can ever hope to exhibit. And all this may be actually observed in the eye of an animal recently killed. By cutting out a circular portion of the outer coat at the back part of the eye of an ox or sheep, for example, this beautiful picture may at any time be witnessed. An eye, thus prepared and held up at the window, will have presented on its posterior surface a perfect, but inverted, representation of objects, whether stationary or in motion. The same is likewise shown in an optical instrument, resembling the eye in form, or in the camera obscura.



[Inverted picture on the retina; a portion of the sclerotic and choroid tunics being removed from the back part of the eye.]

Thus we perceive that vision is a very differen function, and is effected in a very different manner, from that of touch. We have said, that when an object is presented to the latter sense, we feel the actual object itself; but it is quite otherwise with the eye; for when any object is examined by this organ, that object is itself not seen, paradoxical as it may seem,—it is but the picture of the object which is contemplated. And this is a very beautiful contrivance; for if, in order to be conscious of the existence of any object, it were necessary to come in contact with it, how many objects are there of which we could never have the slightest knowledge? Dr. Reid has observed that "if a man were by feeling to find out the figure of the peak of Teneriffe, or even of St. Peter's Church at Rome, it would be the work of a lifetime." But the eye, when accustomed to observe, and to associate its impressions with those of the other senses, can at once ascertain the figure, size, position, &c., of most terrestrial objects. It is marvellous, indeed, how all these can be discerned so readily, when we consider that such numerous and diversified objects as we are constantly surveying are represented on so small a screen as the retina of the eye, occupying a space not larger than a shilling!—that the largest mountains and the most stupendous pyramids can be delineated on so minute a canvass! In allusion to this picture, represented in the bottom of the eye, we may truly ask, in the language of the poet, "who can paint like Nature?" It is formed upon principles so unerring that it is, and necessarily must be, the perfection of all art, for it is nature.

Now this natural picture is produced, in like manner as an artificial picture, simply by variations of light and shade. It is obvious that if we hold any object between the eye and the light, (the organ being perfectly transparent,) a shadow will be projected on the bottom of the eye; that shadow will correspond with the form of the object held up, and we shall have a picture of it there, in the same manner as there would be upon a wall or any other surface. Perhaps this is the simplest way in which the subject can be explained, and it was in this way that pictorial objects were first represented, by shadows or outlines projected against a wall. Moreover, we shall perceive, that as light is given off from all surrounding bodies,—is in a state of constant motion, traversing the interval between one body and another,—if we direct the eye to any given object, the light coming from that object will enter the eye and strike upon the retina, and an image will be formed there. But we must remark on this point, that what is true of bodies in general, is not so of such as we term black; for these, instead of throwing off or reflecting light, absorb it all; whilst, on the contrary, such as we term white absorb none, but reflect all. Other bodies, however, absorb only a certain portion of the light and reflect the rest; and this is the foundation of colour; for light, although ordinarily colourless, is divisible into several coloured portions; and accordingly as different bodies give off these differently coloured portions of light, we are provided with that beautiful and diversified appearance which everywhere meets our view.

Thus we perceive that objects are represented in the bottom of the eye by the light which is reflected from them; and in this way we have a picture, not only of their figure, as in the representation of shadows, but also of their colour, and that infinitely surpassing the most exquisite productions of art.

What can be more curious than the manner in which the letters of a book are depicted in the eye? The white light from the paper is reflected from the book into the organ; but where the letters are, there are so many blank spaces, so many points from which no light is reflected; and these form on the retina corresponding vacant spots, twisted and turned in various ways,—fac-similes of the letters themselves,—and yet capable of conveying to the mind information of the most varied and astonishing description. So that the letters of a book leave blank spaces on the retina of the eye, and are themselves positively nothing—are divested even of light, the most evanescent and the least tangible of all material substances, if indeed it be material at all. If, however, red letters are used, then there is a reflection of the red rays, as well as the colourless rays from the paper, and these are projected into the eye and have the shape of the letters they are reflected from. Hereafter we shall have an opportunity of explaining the manner in which the rays of light pass through the transparent media of the eye, so as to produce a picture of the object from which they come.

This appears to be all the explanation that can be given on the subject of vision. In what manner the picture is conveyed to the sentient part, the mind, so as to give to it actual knowledge, it is difficult even to conceive. All that can be said is, that the mind perceives the picture, as through a certain other part of the nervous system it perceives that a body is round or hard.

Some suppose that light passing into the eye produces vibrations on the retina, and that these originate ideas of colour in the mind; but that vision is strictly referrible to this picture, and cannot exist without it, appears to be as certain as anything we know of; for the least interruption to the formation of this picture, in the same proportion, interrupts vision. Thus a person who is near-sighted shall be actually incapable of seeing certain objects at all, without the aid of glasses, and this not from want of light, but because of an imperfect image in the eye. Let there be but a perfect image pictured upon the nervous membrane of the eye, and there shall be perfect vision, provided the nervous structure be in a healthy condition. Then how unreasonable to suppose that Nature would have been so profuse in supplying the necessary apparatus for procuring pictures, if vibrations were alone sufficient to produce vision!

Now, if we had it not in our power to elicit a single fresh fact with respect to the eye and vision, we should find ample evidence in what has already been stated of the existence of a superintending and benevolent Creator, who has had especially in view the enjoyment and well-being of his creatures. For we cannot fail to perceive that had man been formed destitute of this noble faculty, the rest of creation being the same, what a barren wilderness this glorious world would have been! In vain the enlivening beams of the sun would have darted from that fiery orb,—in vain the beautiful and variegated appearance everywhere present through the agency of those beams,—in vain the smiling landscape, the colours of the rainbow, the blue sky, the spangled heavens, the undulating hill and dale, the green verdure, the beautiful plumage of birds, and more than all, the expressive countenance of man, and the endearing smile of his better and fairer counterpart. All these, and a thousand other beauties, which tend to cheer the heart of man, and to display the boundless power of God, would have remained unnoticed and been made in vain, since, without vision, they could not have been rendered apparent to his perceptive faculties.

CHAPTER III.

General view of the Structure of the Eye—Its superior Construction, as compared with Optical Instruments—The numerous instances of design it exhibits.

The form of the eye is nearly spherical. Hence it is usually called the eye-ball, the globe, or the apple of the eye. Of this we could not be aware, had it not been made the subject of notice, when removed from the position it occupies in the living body. Otherwise, we could only know that the portion of it, which is open to observation, has a convex surface, which implies that it forms a part of a sphere. It is divided into its lenses or humors, and tunics or coats. The former are transparent, the latter partly transparent, partly opaque.

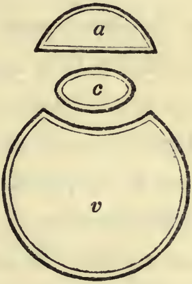
[Form of the Eye.]

It has many accessory parts likewise, all of which will be noticed in their proper places.

Ever since the structure of the visual organ was first made the subject of observation, it has been invariably regarded as exhibiting the most convincing proofs of design in its organization and functions. The examination of its internal construction has led philosophers to perceive that it far surpasses all human contrivances; and we find that artificers, when they wish to produce a tolerably perfect optical instrument, best effect that end by imitating, as closely as possible, the mechanism of this organ.

In illustration of these points we may refer, in the first place, to the manner in which the adjustment of an optical instrument is effected, so as to give a perfect image of objects placed at different distances; for, it is a law, with respect to these instruments, that the same adaptation of them, which gives a correct picture of a distant object, will give an imperfect picture of a near object, and the reverse. Well, philosophers had no sooner discovered this law than they immediately commenced a search for the means by which the eye—the master-piece of optical skill—adapts itself so as to obviate this difficulty; and many, and very opposite, and all equally unsatisfactory, have been the explanations they have suggested. By this analogy, comparing so imperfect a production as a camera obscura, or a telescope, with that perfect instrument, the eye, they have created a difficulty which they have never been able to surmount. Strange to say, they have actually *created* the difficulty, for it may be easily ascertained, by any one, that no such change, as the one alluded to, is at all necessary in the eye. I have made many observations, which have convinced me of the truth of this assertion. Having procured some very fresh eyes of animals recently killed, to my great surprise, I found that all objects, whether near or at some distance, were perfectly represented in these eyes; and, if this be the case in the dead eye, how much more perfect must it be during life? Majendie informs us, too, that he made similar observations on the eye of an Albino animal. Dr. Milligan, the learned translator of that celebrated author's work on physiology, after stating that the immortal Haller showed that there is no such thing as this adjustment in the eye, says, "philosophers, however, have clung to this venerable bubble with as much tenacity as they formerly did to their beards." Philosophers, in short, have failed to see that this adjusting power, which it is necessary to give to their optical instruments, is at once a proof of the imperfection of those instruments, and of the beautiful perfection of the visual organ.

There are also other imperfections which exist in optical instruments, that are not observed in the eye. Such is that termed *spherical aberration*, which arises from the shape of the lens; as well as that of *chromatic aberration*, or, the change of colour, noticed in the passing of the rays of light through that body. It cannot be a matter of surprise that a mere lump of glass, the work of human hands, should be incapable of producing such masterly effects, as are observable in the humors of the eye. Now, it were much more scientific, and more in accordance with the dictates of reason, that opticians, in order more nearly to approach perfection, should form their instruments, as far as possible, on the model of this organ. By so doing, they would probably improve their own productions, and thus be prevented from attributing imperfections to the eye, which it does not possess, and consequently from having to seek for the means of remedying them. Thus it is found, that, by having recourse to a complication of lenses, spherical aberration is destroyed. This improvement was suggested by Mr. Dollond, and we shall find, that in this he imitated the arrangement of the lenses, or humors of the eye. The accompanying diagram represents the three humors of the eye; they all differ in form and size, and are all of a different consistence.



[Diagram of the humors; *a* represents the aqueous, *c* the crystalline, *v* the vitreous.]

Now, it has been so much the custom of physiologists to talk about the *lens*, meaning thereby the central or crystalline lens, that they would seem actually not to regard the other humors as being also lenses. Thus the aqueous humor is seldom spoken of but simply as the aqueous humor, a very convenient and suitable fluid, which allows the rays of light to pass through it, refracting them a little, perhaps, but of no importance. And so the vitreous humor,—it was necessary to occupy the posterior chamber with something, and therefore the vitreous humor was put there, perhaps because nature abhors a vacuum. But it is very clear that there was some special intention, that there was an end to be accomplished, otherwise we should not have had all the lenses of the eye thus differing in form, in size, and in consistence. By these differences in the lenses not only is spherical aberration prevented, but the eye is rendered an achromatic instrument.* Hence it is found that by making their artificial lenses of different densities, and therefore of different refractive powers, and thus by imitating as closely as possible the humors of the eye which have these different properties, opticians also render their instruments achromatic,—colourless; and, indeed, so perfect, that they consider themselves entitled to apply to them the term aplanatic,—free from all errors. It may be a matter of doubt, however, whether they are at present entitled to use such a term, particularly so long as the work of adjustment is essential to the proper use of their instruments.

---

* The subjects of spherical and chromatic aberration will be found more fully explained in Chap. V.

After all, however, and when they have done their best, what have they produced? Why a mere inanimate tube, or a ball, capable, when held up to the light, of giving an image in some sort as the eye does; but which is very little like this sparkling orb, beaming with light, life, intelligence, and beauty. It is true that when we examine the various optical contrivances which human ingenuity has formed, we are pleased with the skill which they exhibit, and the effects they are capable of producing; but what do they amount to when contrasted with the organ itself?

Many ingenious contrivances are, at the present day, made to assist the anatomist in his task of illustrating this beautiful portion of the animal economy. Imitations of the organ are formed from various substances, such as glass, ivory, enamel, and wax; and many splendid drawings and engravings are exhibited. But, can we, for a moment, compare the lump of glass, which is employed to represent the lenses, with those perfectly translucent humors, more beautifully clear than the finest crystal? Can we venture a comparison between the polished ivory, or the supple wax, with the flexible natural covering? What resemblance is there between the sliny paint, which is daubed on the inside of all optical instruments, and the pigment which is employed for the same purpose by nature? Where is the contrivance that is to represent that most delicate and slender web of nervous matter, the retina? Whither shall we direct ourselves to find out a combination of colours that shall rival that variegated membrane, the iris, or the beautiful tapetum, found in the eyes of some animals?

With respect to the proofs of design, they are noticed in every portion of the organ, for every part is adapted to some particular purpose. Thus, the external tunics are formed for defence, and are provided with the necessary degree of firmness. Being elastic, they yield to force, and recover their shape when it has passed away; whilst they are so tough that it requires the sharpest and finest instrument to penetrate them. At the anterior and central portion of the eye-ball, this firm, almost horny texture (from thence called *cornea*), in addition to the purposes of defence, is also designed for a window, which purpose it strictly answers; for this end it must of course be transparent, and, it is so, in such a degree, that it is hardly discernible by those who are unaware of its existence; thus combining two qualities of the most admirable character, *viz.* great firmness and the most perfect transparency.

Behind this window we notice that beautiful structure, the *iris,* which stretches across the interior of the eye, and fulfils the office of a blind. A more elegant apparatus than this the whole of nature does not contain. It has an aperture in its centre, which is capable of being enlarged or diminished, by the action of two opposite sets of fibres, so as to admit more or less light, as may be agreeable or useful for the purposes of accurate vision; for, in the dark, it expands very considerably, and when in bright sunshine, or any strong light, as well as during the period of sleep, it becomes nearly closed. The back part of this structure is covered with a coat of dark-coloured varnish, for the obvious purpose that it may be quite impervious to light, which it otherwise would not be, so extremely delicate is the texture of this membrane; for it is essential that no light should pass into the eye, but through the pupil. Indeed, the whole of the interior of the eye, posterior to the iris, is lined with the same pigment, for the like purpose, as well as to prevent all reflection of the light that enters at the pupil. The optician finds it necessary to paint the inner walls of his camera obscura, for precisely the same reason. In some nocturnal animals, and in fishes, on the other hand, we find colours of a lighter tint,—purple, green, silver, and gold, for the very purpose of reflecting the concentrated light of the eye upon objects they are in pursuit of, when in the dark, an excellent example of which is seen in the cat.

Not only is there a window and a blind, but there are also beautiful folds of drapery (*ciliary processes*) hung up behind the iris, embracing the crystalline humor, and keeping it suspended in the centre of the eye; these are dyed with the same colouring matter as the rest of the posterior chamber, and with the same view.

We might be led to suppose that the inner chamber of the eye would be of a rather sombre and dismal character, from the great care which has been taken to limit the supply of light. On the contrary, when all its parts are perfect, a more animated scene can hardly be imagined, than that which is constantly represented within it, when the eye is engaged in surveying the different appearances of nature. Its walls are continually ornamented with the most beautiful and ever-changing pictures, of the richest tints and of the most gorgeous colours,—a transcript of Nature by her own hand.

Is there not equal design evinced in the formation of the beautifully transparent *lenses?* for, if these were not transparent, no light could penetrate them, and the purposes of the organ would be entirely frustrated. We have a most striking proof of this in the disease termed *cataract.* In this affection, the central or crystalline lens becomes opaque, loses its transparency, and refuses to permit the rays of light to pass through it; hence there will be no image formed in the bottom of the eye, and the individual will therefore be blind. So that an infant, who is born with this single defect, arrives in the world without the means of taking cognizance, in the direct manner which the eye affords, of the larger portion of created nature, and will be almost in as pitiable a state, as if he had no eye at all; for the slight vision which he is allowed in this condition will be of but little avail, although the bare possession of the faculty of perceiving light will be a source of great enjoyment to such an individual, and one which he would not part with on any consideration. Yet will he be utterly incapable of receiving the astonishing advantages and pleasures which result from perfect sight. Luckily, however, for him, the skill of the surgeon is generally sufficient, in a great degree, to remedy this defect, by removing, either from the eye, or out of the axis of vision, the opaque body. Fortunately, too, the other humors are not liable to this opacity; but the cornea, the window of the eye, frequently becomes so, with the same effect as when the crystalline is so impaired; and thus from the very imperfections and diseases to which these parts are occasionally subject, we draw convincing proofs of the necessity for their being transparent, and of the evident marks of contrivance which they present in being so formed.

All these parts being thus perfected with the design of producing images of external objects, lastly, we find a delicate nervous membrane, the *retina,* placed all around the internal concave surface of the posterior chamber, for the express purpose of communicating those refined and subtle impressions to the brain.

Hitherto we have noticed only the structures of the eye-ball itself; but how many accessory parts are necessary to the proper performance of its functions! As we proceed, we shall find it amply endowed with appendages, without which it would be of but little avail, as will be abundantly proved on examination of them.

Similar evidence of the most apparent contrivance is offered in the formation of the *eye-lids.* How admirably are they constructed for protecting the eye itself from injury, closing over it with the most perfect accuracy! If the smallest particle of matter gets blown upon the eye, instantly the lids contract to squeeze out the offender. With what inconceivable rapidity they close to prevent the threatened intrusion! The twinkling of an eye has been proverbial, for the velocity with which it is effected, doubtless, since the period it was first noticed.

This action is accomplished by means of a muscle, inserted into the substance of the lids, and which, when put in motion, draws the margins of each lid into close contact, somewhat in the manner of the mouth of a purse, and this action is always present in sleep. Perhaps the utility of it is most forcibly shown by reference to the unfortunate condition of that individual who labours under a paralysis of this muscle. This is always the result of some disease either of the nerve which endows the muscle with this power, or of the part of the brain from which this nerve arises, or with which it is connected. In this state the eye is left without this power of excluding any irritating matter from its surface, and great is the suffering and inconvenience which is experienced. During sleep the eye is left exposed to various sources of irritation; and, from this and other causes, it not unfrequently happens that the cornea becomes opaque and vision entirely lost.

Now, when we awake, after enjoying the balmy influence of sleep, another muscle is called into action, which is the antagonist of the former, and which is inserted into the upper lid, and raises it in the manner of a drop-curtain, placed before the eye, which in fact it is. This muscle pulls up the superior lid, and thus the front of the eye is exposed, and the organ is ready for the performance of its functions. By a paralysis of this muscle, the individual, who is the subject of it, would lose the ability to separate the lids, or, in common language, to open his eyes. A most unfortunate condition this would be, for a person thus situated, before he could make any use of his eyes, would be obliged to push up the superior eye-lids with his fingers;

and the moment the fingers were removed, the lids would again drop over the front of the eye, and he would be in a condition as if he were blind, although his vision might be unaffected. Nor are these mere hypothetical cases, got up for the sake of effect, but, on the contrary, they are of frequent occurrence; and, by contrasting them with the healthy condition, we obtain evidence of the most conclusive character of the great care which has been taken in the formation of this structure.

We may refer even to the eye-lashes, the *cilia*, for the same purpose. They are planted in the margins of the lids in a manner perfectly harmonious with the general design. It is beautiful to observe the graceful curve which they form; those in the upper lid sweeping upwards, those in the lower lid downwards, the convexities of each intertwining with one another when the lids are in contact, the whole forming a beautiful trellis-work, which is at once an ornament of the most pleasing character, and a sufficient defence to prevent the lodgment of very small particles of dust upon the eye. That these require to be inserted in this particular manner is proved by the fact, that if, from any cause, they become changed in their direction and turn inwards upon the eye, instead of being a useful means of defence, they are a source of the most terrible annoyance, so great is the distress they cause; and, in this way also, loss of vision frequently results.

We have now referred to the principal means of defence which the organ possesses. It has, however, many other accessory parts. An important portion consists of the glandular or *lacrymal apparatus,* by which it is lubricated and watered, so that the lids may move upon the eye-ball with the most perfect freedom. We notice first the lacrymal gland. It is lodged in the upper and anterior part of the orbit, the common receptacle of the eye and its more important accessories. It is at once a laboratory and a fountain. In this little organ one of the most interesting operations of the animal economy is in constant progress. It is here that, by a process of animal chemistry, the red blood, the common parent of all the secretions, is converted into the colourless fluid which is called *tears.* No sooner is this fluid formed than it is conducted away by several small tubes, whose openings are visible upon the inner surface of the superior eyelid. From these it passes over and moistens the surface of the eye, and, when it has effected that purpose, is carried off. But how is it carried off? Is it allowed to run from the lids and drop down any how over the cheeks? No: a special provision is found. In the inner corner, one in each eye-lid, are two very minute apertures, which are the orifices of two canals, which communicate with a duct or pipe, by which the superfluous moisture from the eye is drained off and conveyed away into the nostrils. All this goes on in a manner perfectly calm, regular, and unobserved, under ordinary circumstances; but when irritation is set up, then the natural channels are insufficient for their escape, and the tears roll over the cheeks in a rapid current. This flood of tears, for a constancy, would be a serious inconvenience; but it seems to be productive of relief when the organ is suffering from irritation, and is useful in washing away foreign matters from its surface. What annoyance is occasioned by an obstruction of the nasal duct; for then, instead of the tears being carried off by this natural channel, they flow over the margins of the lids and trickle down the face, a source of unceasing trouble to the unhappy sufferer.

In order that the eye may not remain fixed in one position, and therefore stationary, it is provided with extensive powers of motion. Here, again, we find an adaptation of means to the wants of the beings for whose advantage this power is bestowed. For man and the higher animals it would have been, at least, exceedingly inconvenient to have had the eyes fixed in one direction. So situated, the faculty of vision would have been much more limited, and we should have had considerable difficulty in discovering the position of many objects by which we are surrounded. In order, then, to effect the various movements which are necessary for the boundless range of vision which we enjoy, a system of *muscles* is placed around and in contact with the globe of the eye, by whose slightest contractions the eyes are turned, with the rapidity almost of thought, in every possible position, by whose action they are directed to all points of the visible horizon, and can sweep at will along the surface of the earth, or through the boundless realms of space! For this purpose, too, the shape of the eye,—a sphere, placed in the centre of its orbit,—is the best that could have been chosen, it being a well-known fact, that the motions of a spherical body are more easily excited than those of one possessed of an angular form.

To give to the eyes these powers of motion there are no less than six muscles connected with each. Four of them, passing in a straight direction from the bottom of the orbit, where they arise, are planted around the circumference of the globe; whilst the other two are differently directed: one arises in front of the orbit, passes at an angle to the circumference of the globe, at its inferior portion, and is inserted on its outer and lower side; and the other, the most remarkable of all, takes its origin with the first four, passes along the upper and inner part of the orbit, and, at its front, goes through a pulley, provided for its reception, and finally is also directed at an angle to the outer circumference of the globe, passing over its upper surface. The manner in which this latter muscle traverses the orbit, and, at its outlet, passes through this natural pulley, forms, perhaps, the most palpable of all the marks of contrivance which are here so profusely exhibited. That there must have been an object and a very important end in view, in the formation of this complicated piece of mechanism, no one, on reflection, can possibly doubt; and it must therefore seem a matter of surprise that authors of celebrity should be found who doubt of the use of the oblique muscles, (for so these two latter are called,) conceiving that every action which we possess over the eyes could have been as well accomplished by the aid of the four straight muscles simply. Very unlikely indeed, that so much ingenuity, skill, and contrivance should be employed to no purpose. Of this, however, more hereafter.

When we have learned duly to appreciate the important functions connected with vision, and when we reflect on the number and variety of parts subservient to that sense, as well as the exquisitely refined sensibility of the organ itself and its complicated movements, we shall not be surprised at the profuse supply of *nerves* which we see distributed to its various parts. The nerves are the conductors of all the vital powers and energies of the system. Place a cord around one, or cut it across, anywhere between its connexion with the brain and the part to which it is distributed, and that part instantly loses all power of sense or motion, according to the property which the nerve bestows upon it. Hence, without the nerves, the eye itself, the eye-lids, the lacrymal apparatus, the muscles, would be all useless, inert, motionless, and inanimate. In proportion as the functions of an organ are simple, so will be the arrangement of its nerves: when they are complicated, the nerves will be numerous, intricate, and very difficult of arrangement. This is the case most remarkably in the eye: no organ can be at all compared with it in this respect, for there is no portion of the body so profusely supplied with them as this. If we but glance at a map* of them, we see at once how complicated, numerous, and unintelligible they appear; and yet are they all designed for special purposes. Their intricacy and complexity is best illustrated by the fact that, of the ten nerves which go off from the brain, no less than six are distributed to this organ, four exclusively, the other two partially.

As well as the various parts we have mentioned, which go to make up this small portion of the animal economy, there is also the apparatus for supplying nutrition, consisting of the arteries, which circulate the blood, and the veins and absorbents, which remove the old and useless matters, and return the blood to be purified. The blood is at once the parent and regenerator of every part of the system. However opposite in appearance, however different in form and structure, whether the more than crystal transparency of the humors, the dark colouring matter of the pigment, or the opaque, firm, and fibrous texture of the outer coat of the eye, all are alike eliminated from one common source, the fountain of all life, the blood. This system, then, is as essential as any of the others we have noticed to the due and healthy action of the various parts of the eye, for it is not only an optical machine, but it is also a living organ.

---

* See frontispiece.

We have thus given a brief and rapid sketch of the more prominent proofs of intelligence and design, which are so extensively exhibited in this most interesting organ. In the following chapters, as we enter more into detail, we shall find still farther and equally remarkable evidences of the like description. Here, however, we might safely take our stand, and, from the facts already adduced, justly conclude that, if there be any one thing in nature more beautiful than another,—if there be any one thing more exquisitely contrived than another,—if there be any one thing which shows the power, wisdom, and benevolence of the Great Author of Nature more than another, it surely must be the mechanism which we have endeavoured thus feebly and imperfectly to describe, and which, from its surprising powers and faculties, may be justly termed the very paragon of organs.

CHAPTER IV.

Of the Means by which Images of Objects are produced— The Lenses of the Eye.

THE intention of the Deity in giving to his creatures the beautiful and complicated apparatus we are now considering, was, unquestionably, to present them with the readiest and most effective means of becoming acquainted with the various objects by which they are surrounded on every hand in the material world. The necessity that exists for such an apparatus has been already indicated by what has been said before. We have seen, also, that vision is effected by pictures of the objects contemplated being presented, through this apparatus, to the sentient organ, the brain.

Now the means by which these pictures are formed, viz., the transparent media of the eye, are similar, though at the same time infinitely superior, to those which man's experience has taught him gradually to perceive would produce the like results. He has arrived at this knowledge by slow and imperceptible gradations. The observation of an accidental occurrence led him first of all to perceive the manner in which a transparent and durable substance might be formed from two bodies which, previous to their union by fire, were perfectly opaque. He was not long in observing further, that objects are seen almost as clearly when viewed through a piece of glass, as when simply through atmospheric air; and he afterwards ascertained that this substance has the property of reflecting as well as transmitting light. Moulding it into various forms, such as his ingenuity, caprice, or judgment might dictate, he would gradually become conversant with many others of the wonderful phenomena it is capable of presenting. At length he would perceive that spheres, or certain portions of them called lenses, have the property of producing very exact representations of objects which are held up to them, by means of the light transmitted through their substance.

From this point to that of the formation of the telescope, the microscope, and the camera obscura, the steps were slow but certain. All this was ascertained without reference to the eye. How this organ is useful in producing vision was unknown until the discovery of the camera obscura by Baptista Porta. Previously it was thought that the eye has the power of emitting some peculiar principle, from itself, upon exterior objects, and of thus rendering them visible. Of course, had this been the case, there need be no such a state as that of darkness, except when the eyes are closed. As Sir John Herschel has remarked, "the camera obscura, invented by Baptista Porta in 1560, gave the first idea how the actual images of external objects might be conveyed into the eye; but it was not till after a considerable interval that Kepler, the immortal discoverer of those great laws which regulate the periods and motions of the planets, pointed out distinctly the offices performed by the several parts of the eye in the act of vision."* With what profound delight must those master-minds have contemplated the approach, distant and humble as it was, which the accumulated information of their predecessors, and their own skill, had enabled them to make to the superior workmanship of the Creator!

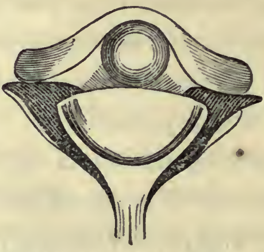
From all this, then, we are led to the inference that it is the lenses, the transparent humors, that are the instruments of highest importance, the prime agents, in the process of vision. And so, on examination, we shall find that these form the great bulk of the eye, and that all the rest is but subordinate and accessory to them, because by these alone are the images of objects produced.

---

* Cabinet Cyclopædia.

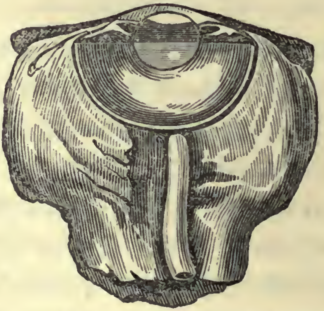
On contemplating the lenses or humors of the eye, we cannot fail to be struck with the remarkable difference they present in shape, size, and consistence, notwithstanding that they are all perfectly translucent. They are three in number, as shown in the diagram in the last chapter. The anterior, situated in the front of the eye, is called the aqueous humor, the middle one the crystalline, and the posterior the vitreous; terms expressive, at least, of their most marked and common character, transparency.

The most efficient and the most important of the three is, undoubtedly, the central or *crystalline* humor or lens. It is found to exist in almost the lowest grade of animals, in those, at least, which possess what may be strictly termed vision, and in which it is possible to discriminate one portion of the organ from another. It is much more generally met with than the aqueous humor, the latter being absent in most of the lower animals, whilst the vitreous is always present with the crystalline.

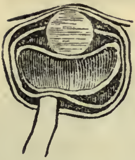


[Section of the eye of the scorpion, class Arachnida. The round crystalline lens is placed upon, but not embedded in, the vitreous humor beneath.]

In fishes, too, there is scarcely any aqueous humor, and the vitreous exists in a much less degree than in the higher classes of animals; whereas the crystalline, on the contrary, is very large and globular, and occupies a considerable space in the interior of the eye.

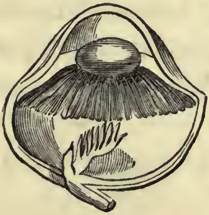


[Section of the eye of a whale. The crystalline spherical and embedded in the vitreous humor; the aqueous absent; the optic nerve perforating the eye-ball beneath, surrounded by fatty matter.]



[Section of the eye of the perch.]

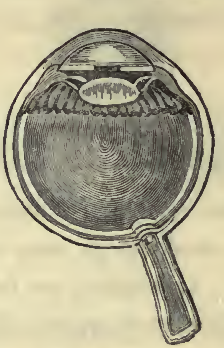
A very similar condition is noticed in the amphibia, slightly modified to suit their somewhat different habits. In reptiles, we find the vitreous and aqueous humors occupying a larger space, and the crystalline a smaller. This increase of the vitreous and aqueous humors, and diminution of the crystalline, is still more marked in birds.



[Section of the eye of the bird; the aqueous humor occupying the anterior chamber in front of the crystalline; the marsupium or pecten passing from near the optic nerve into the vitreous humor.]

In quadrupeds, the proportions are somewhat different, the aqueous humor being less considerable, and the crystalline larger; whilst in man, the crystalline is smaller, as it is also in birds.

The shape of the crystalline also differs with its



[Section of the human eye.]

size. When it is large it is always more nearly spherical, as is observed in the lower animals and in fishes; and when it recedes in size, as it does in quadrupeds, in birds, and in man, it becomes flatter, but always more or less convex, both anteriorly and posteriorly.

[The crystalline of the human eye.]

It is a circumstance worthy of especial notice, that we always find a remarkable agreement between the media, by which the different orders of beings are surrounded, and the conformation of the transparent humors of the eye. Thus in the amphibia, which exist for the most part in water, a much denser medium than atmospheric air, and in fishes, an aqueous humor in the eye would be of but little or no avail, since its density is not greater than that of the watery medium by which they are surrounded, and therefore it would be incapable of refracting the rays of light. It thus becomes necessary to provide a refracting power within the eye, which shall answer the purpose the aqueous humor is unfit for. It is found in the large, spherical crystalline lens, whose density is much greater than that of the aqueous and vitreous humors. Indeed the whole eye, and consequently the extent of the humors, in the inhabitants of the deep is considerable, because they exist in a very dense medium, through which light with difficulty penetrates to any great depth. Hence they are provided with this large eye to collect as much light as possible in their comparatively dark abode. Thus, in the codfish, the eye is found to be many times the size of any animal existing in the air of the same dimensions.

In those animals, on the other hand, which exist in atmospheric air, and in which the aqueous humor is considerable, this fluid is capable of producing a very high degree of refraction, and hence the crystalline humor is flatter and occupies a smaller space in the eye. This is the case remarkably in birds: they rise to great elevations in the air, and the higher they rise the greater is the rarefaction of the air, and, consequently, the greater is the refraction of the rays of light in passing through the aqueous humor. Accordingly, we find the crystalline flatter and smaller. In aquatic birds, indeed, which dip into the water for prey, the aqueous humor is less in amount and the anterior chamber flatter. To compensate them the crystalline is more spherical and larger. In man, this relation between the various humors is correctly and beautifully established, the aqueous humor being more considerable, and the crystalline rather flat and small.

The same relation we find to exist with respect to the vitreous and the other humors. The quantity of the vitreous is regulated by the degree of refractive power possessed by the aqueous and crystalline humors. It is of much less density than the crystalline, and possessing usually a concave anterior surface, has a tendency to give a degree of divergence to the rays of light, and thus remedy the excessive refraction of the other humors. Hence we observe it less considerable in the lower animals and in fishes, which have no aqueous humor, and the opposite in birds, in quadrupeds, and in man.

Thus we always find a strict relation existing between the size and conformation of the different humors of the eye, and of the circumstances and situation of the creatures to which they belong.

We have before remarked that the humors differ in density. Thus the crystalline is by far the firmest of these bodies. Its *consistence* is that of soft gum, being rather firmer than jelly, yielding to the pressure of the finger, but retaining its shape when handled without pressure. In this respect, however, it differs at various periods of life, for in old age it is generally much firmer than at the middle period, whilst in infancy it is just the reverse. It varies likewise in size, for in early life it gradually enlarges, and in old age diminishes, as it becomes firmer. The same change is noticed with regard to its shape, for in the fœtal stage, and in infancy, it is nearly spherical, but afterwards becomes flatter. We are now alluding to the crystalline of the human eye. And this change in the figure of the crystalline is attended with a corresponding change in the perfection of vision; for its spherical form, in infancy, renders the eye near-sighted, and its flattened shape, in old age, produces the opposite condition.

In *size,* at the middle period of life, the crystalline is, in breadth, about four lines, or a third of an inch; its thickness, two lines. At the same period, its shape is that of a double convex lens, its posterior being more convex than its anterior surface. A lens having this shape is termed, by opticians, a *crossed* lens.

The *position* of the crystalline in the eye is immediately behind the iris and the aqueous humor, and between them and the vitreous humor. Its centre is placed immediately opposite to that of the pupil, so that the axes of the two correspond. By the *axis* of a lens is meant a line drawn from the middle of its anterior convexity to the same point of its posterior convexity, passing through its centre.

The *texture* of the crystalline presents a series of

[Laminated structure of the crystalline.]

concentric layers, which become firmer in consistence as we approach its nucleus or centre, and which are regarded to be of a fibrous character. Sir David Brewster has computed the number of fibres in the crystalline of a cod-fish at five millions, which, he says, are connected together by means of sixty-two thousand five hundred millions of teeth!

Dr. Thomas Young, the celebrated Leuwenhöeck, and John Hunter, believed this texture to be muscular. The first of these highly-gifted men has described not only what he conceives to be its muscles, but their tendons likewise. It is necessary to premise, that those who entertain this view adopt it as the basis of a theory of the supposed adjustment of the eye to different distances, being accomplished by a change of figure in the crystalline humor. Without intending to reflect improperly, in the least degree, upon the memory of these illustrious names, we may still be permitted to remark, that, in this, as in many other instances, the theory was first formed, and the muscles of this structure were afterwards explored.

Dr. Young, after premising the *absolute necessity* of an increased convexity of the crystalline lens, when inspecting objects very near the eye, says, " The crystalline lens of the ox is an orbicular convex, transparent body, composed of a considerable number of similar coats, of which the exterior closely adhere to the interior. Each of these coats consists of six muscles, intermixed with a gelatinous substance, and attached to six membranous tendons. Three of the tendons are anterior, three posterior; their length is about two-thirds of the semi-diameter of their coat; their arrangement is that of three equal and equi-distant rays, meeting in the axis of the crystalline; one of the anterior is directed towards the outer angle of the eye, and one of the posterior towards the inner angle, so that the posterior are placed opposite to the middle of the interstices of the anterior; and planes passing through each of the six, and through the axis, would mark on either surface six regular and equi-distant rays. The muscular fibres arise from both sides of each tendon; they diverge till they reach the greatest circumference of the coat, and, having passed it, they again converge, till they are attached respectively to the sides of the nearest tendon of the opposite surface. The anterior or posterior portion of the six, viewed together, exhibit the appearance of three penniformi-radiated muscles.

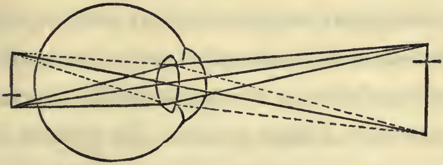
The anterior tendons of all the coats are situated in the same planes, and the posterior ones in the continuations of these planes, beyond the axis."

That this curious arrangement exists may be strictly correct, and yet, notwithstanding, these fibres may not possess any power of contraction or dilatation, as muscular fibres do. The mixed composition of this body, partly solid, partly fluid, and all transparent, may require its fibres to be so placed, one over another, in layers, with the fluid part interposed; whilst the form and direction these fibres take may probably be regulated, in a great measure, by the shape of this body.

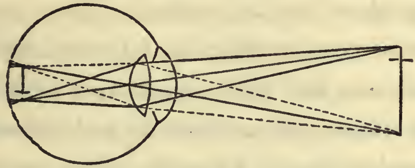
Many persons deny the existence of muscularity in parts that possess an evident power of motion; but here that evidence is entirely wanting, for no one ever pretends to have seen this body with its fibres in a state of motion. We have before remarked, that it was by observing the phenomena presented by the passage of light through glass lenses, that philosophers were led to presume that, because an adaptation to different distances is requisite in these substances, the same adaptation is also necessary in the eye. And here was their grand error in drawing an analogy where none properly existed. For, although they could mould a lump of glass into the shape and size of the crystalline lens, yet could they not imitate the organization and internal arrangement of this most beautiful texture. In the one we find a simple homogeneous substance, moulded into a certain shape, with its density uniform throughout ; in the other, we have seen that it consists of very different materials, arranged in a manner the most curious that we can possibly conceive, possessing different degrees of density throughout, and altogether affording an instance of the immeasurable superiority of the works of nature over the most finished and ambitious productions of man. Can two substances, then, so opposite in these respects, be considered as affording grounds for analogy or comparison? Only to a very limited extent certainly.

Besides, if, as Dr. Young supposed, this increased convexity of the crystalline be produced by muscular action, and if both be necessary to an accurate representation of a near object, then these effects could not take place after death, since muscular activity and increased convexity cannot then be produced ; and yet we shall find, by making the experiment, that the crystalline after death, while it remains transparent, will give us a perfectly accurate image of any object, however near.

A great deal is constantly said about the construction of the eye in birds, and concerning this power of adapting it to different distances. They have the aqueous humor in much larger quantity, the anterior chamber being more convex, and, consequently, the refraction of the rays of light is much increased, and they are well provided with the means of seeing near objects remarkably well. Hence, it is said, birds require some contrivance by which, when they are at a great height in the atmosphere, they may see objects at a considerable distance on the land, and a provision is therefore necessary for flattening the anterior chamber. This seems to be a difficulty of the opposite kind to that presumed to exist in man and the mammalia, the latter being fancied to require a means of increasing the convexity of the eye for near objects. We have likewise descriptions of contrivances for lengthening the eyes of birds, for rendering them more convex, more prominent. To what purpose? Their eyes are, without such contrivance, very convex, very prominent, and very well adapted to the survey of near objects. Then, again, their eyes are supposed to relax and become flattened, when they wish to see objects at a distance, to become much the same as they are observed to be when dead. Well, if we deny the existence of such contrivances in man and in quadrupeds, why should we allow of it in birds? There is no reason why we should. Because, if the aqueous humor be more considerable, and the anterior chamber more convex, as a set-off we find the crystalline smaller and flatter. And why have we the crystalline flatter, but to compensate for the excessive refraction of the aqueous humor? In birds that are really near-sighted, have we not the crystalline much more spherical, as, for example, the near-sighted owl and aqueous birds? And why are these latter near-sighted, but because of the increased sphericity of the crystalline? In the changes which the eye of man undergoes, from infancy to old age, we see this principle exemplified. In infancy, and in early life, the crystalline is more convex, and the consequence is that the eye is near-sighted. As he proceeds towards old age, the crystalline and aqueous humors have a more flattened form, and he is therefore unable to see near objects without the aid of his convex glasses. He is not so because he has lost the power of adjusting the eye, but simply on account of the change in the figure of the humors.



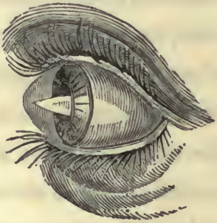
[Presbyopic or far-sighted eye. The lens not sufficiently convex, and the rays therefore concentrated too far back.]



[Myopic or near-sighted eye. The lens too convex, and the rays converged anterior to the retina.]

It appears to me that there is a certain correspondence, in form, between the various humors, which gives the power of pretty accurate vision under all ordinary circumstances; and that, if that correspondence be disturbed, one way or the other, imperfect vision results: if the refractive agents be too convex, then near-sightedness will be produced; or, on the contrary, if they are not sufficiently convex, the eye will be far-sighted. The fact that these deficiencies are remedied by diminishing or increasing the convextiy, by means of artificial lenses, is strongly in favour of this view. Besides, in proof that an eye may be adapted to both near and distant vision, we have only to refer to a short-sighted individual, who, when he is furnished with his concave glasses, is very well qualified for seeing both near and distant objects. It appears to be equally clear, that if we could diminish the convexity of the crystalline and aqueous humors, we should produce the like result.

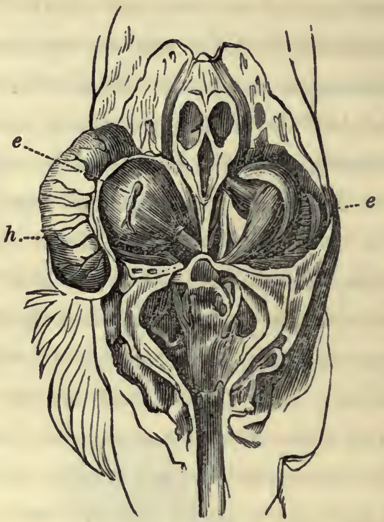
There is a certain affection of the eye, which we frequently see, and which consists of a change of the form of the anterior chamber, and, of course, of its outward covering, the cornea, from its natural convex form to that of a cone.



[Conical cornea, occasioning excessive refraction and myopia.]

Now, with this conical cornea, the refraction is so excessive that the individual can see those objects only which are very near the eye. Hence we perceive how much the shape of the refracting agents influences the correctness of vision; and, we cannot doubt that, as happens with most persons, there is a nice adaptation of the forms of these various humors of the eye to each other, which enables us to see with sufficient accuracy all objects within the ordinary range of vision, and that without any of those mechanical changes in the figure of the humors, which have been so much spoken of.

There can be no doubt, then, that if it were not for this flattening of the crystalline, birds would, like fishes and the lower animals, be enabled to see perfectly such objects only as are near to them; but their eyes, possessing, as they do, a small and flat crystalline with a large and concave vitreous body, have, on the whole, a less refractive power than is generally supposed, the increased refraction of the aqueous humor being counterbalanced by the modifying properties of the other humors. Hence we are justified in inferring that birds are, by the peculiar arrangement of the lenses, enabled to see at all distances with ease. That they possess keener and more extensive powers of vision than most other creatures, is probably owing to the remarkably large size of the eye, as compared with that of the head, similar to what is observed in flying and rapacious insects.



[Base of the skull of a goose, showing the large size of the eye as compared with the head. *e, e,* the eyes. *h,* the Harderian gland.]

The great distance to which birds are supposed to be capable of seeing is not more remarkable than what is observed amongst many uncivilized tribes of men, such as the New Hollanders, New Zealanders, Hottentots, American Indians, &c.

Pallas, speaking of the Calmucks, says, " Nothing is so surprising as the perfection of their eyes, and the extraordinary distance at which they often perceive, from inconsiderable heights, small objects, such as the rising dust caused by cattle or horsemen, more particularly as the undulation of the boundless steppes or plains, and the vapours which rise from and float upon them in warm weather, render things very obscure," &c. &c. The truth of this remark is placed beyond dispute, by authors of the highest rank. And thus we perceive that men and birds possess the most extended range of vision, in accordance with the varied nature of their wants. Nor can we fail to perceive, also, that it is in a great measure owing to the striking similarity that exists in the arrangement of the humors in each.

In the lower animals, the object was simply to enable them to see near objects, confined as they are to a limited circle: this seems to have been effected by a spherical crystalline. The difficulty (if we can suppose a difficulty in the works of the Omnipotent) must have been in forming an eye equally adapted to near and to distant vision; and it seems to have been got over by the addition of an aqueous humor, and the modifying influence of the flattened shape of the crystalline.

To proceed, however, to some more general account of the structure of the crystalline. Notwithstanding that many eminent men have regarded it as possessing muscularity, there have been others who will not allow that it is even vascular: these deny that it has common vitality, because they cannot discern blood-vessels entering into its texture. Of this number was the celebrated French physiologist, BICHAT. Now the evidence on this point is very different from that which is adduced to prove its muscularity. We do not see that it possesses motion, but we do see that it has vitality, because if it be injured, or its connexions with the neighbouring structures broken up, it undergoes a marked and visible change; it is no longer transparent, but becomes muddy and opaque, and of course unfit for discharging its proper functions; and this condition constitutes one variety of the affection termed *cataract*. In this state it ceases to possess the vital power, shrinks, becomes softened, dissolves in the aqueous humor, and finally disappears altogether by absorption. So certain is this process from life to death, from a state of positive existence to that of entire removal, that it becomes an object with the oculist in many cases to imitate this process, when the crystalline becomes opaque from disease. With this view he deliberately introduces a slender instrument into the eye, breaks up the connexion between the crystalline body and the other parts of the organ, and gradually the processes of solution and absorption are accomplished, and the consequent entire removal of the opaque body (the cataract) is effected with the greatest certainty.

A consideration of this point will lead us to regard it as a very improbable supposition, that the crystalline and the other humors should be squeezed about within the eye, as some have fancied,—that the crystalline should be pushed backwards and forwards, by the pressure of the muscles, &c. We cannot but see, that the fine and delicate vessels, which enter into the composition of this structure, must be ruptured by such a process, and that the crystalline would be broken up from its connexions, and its transparency certainly destroyed. Such a condition, indeed, is frequently brought about by blows received on the outside of the eye, as I have myself witnessed in very many instances.

Notwithstanding that the vascularity of the crystalline has been denied by some, there have been other eminent anatomists, as Zinn, Haller, and Winslow, who have asserted that they have seen blood-vessels ramifying into its substance.

Chemical analysis determines that, in addition to water, the crystalline contains a considerable quantity both of gelatine and albumen, and, when reduced to ashes, iron has been discovered; but no trace of fibrine—the base of the muscular tissue, —has ever been observed.

The crystalline humor is surrounded by a fine, transparent, but somewhat firm membrane, called its *capsule.* Like the body it surrounds, it is easily rendered opaque, and is much more difficult of removal. Between the crystalline and its capsule there exists an extremely minute quantity of fluid, called after its discoverer, a celebrated Italian anatomist, *aqua Morgagnii.* The posterior part of this capsule is intimately connected with the capsule of the vitreous humor, and its anterior surface is adherent to a similar membrane surrounding the aqueous humor; so that they are all cemented together in the closest manner possible, and this by materials of such refined and delicate construction as do not, in the least degree, impair the transparency and brilliancy of the whole.

With regard to the peculiarities of the *vitreous* humor, we find that this body is very different in structure, consistence, and density, as compared with the crystalline. Its name is derived from its supposed similarity to molten glass, a substance which it resembles in nothing but transparency, and in that respect it infinitely excels it. It is not homogeneous any more than the crystalline, for it consists of a web-like, cellular texture, containing a large quantity of watery fluid. In the crystalline the water is inconsiderable, and the fibrous structure predominates; whereas, in the vitreous humor, it is just the reverse. If the vitreous body be exposed to the air for a short period, the watery part soon evaporates, but the cellular texture remains; the latter also becomes firm and opaque, if immersed in spirit. When the vitreous body is pricked, or cut with scissors, the water will escape in clear drops from the cells in which it is deposited. By this arrangement the vitreous body, although its watery part is of the same specific gravity as the aqueous humor, as a whole is much denser than the latter, but considerably less so than the crystalline. The vitreous humor occupies the whole of the posterior chamber behind the crystalline. In the human eye it fills up three-fourths of the interior of the globe. The cellular texture, before alluded to, pervades its whole structure, and surrounds it on every side, forming a bond of union between it and the other parts of the eye with which it is in contact. It is named by anatomists the *hyaloid* membrane.

The vitreous body is concave anteriorly, where it unites with the surface of the crystalline, and convex posteriorly, where it is in contact with the nervous membrane, the retina. This figure is termed a *meniscus,* from its resemblance to the shape of the moon at certain periods.

Of the *aqueous* humor, little more need be said. It lies immediately in front of the eye, anterior to the crystalline. It is surrounded by an extremely delicate tunic called the membrane of the aqueous humor, from which this fluid is supposed to be secreted. This membrane is most distinct, and the fluid is also most abundant in the eyes of birds. It lies in very close contact with the internal surface of the transparent cornea, is reflected upon the iris, anteriorly and posteriorly, and finally adheres to the capsule of the crystalline. So that a very small portion of the aqueous humor lies behind the iris, thus permitting the latter to move freely in that fluid. The quantity of this fluid has been estimated at about five drops; but it is evident that it varies in different individuals, because the anterior chamber differs much in extent. Its chemical composition is found to be water, with small quantities of albumen, gelatine, muriate of soda, and phosphate of soda, in solution. It is somewhat heavier than water, its specific gravity being, according to Dr. Henry, 1.009 to water 1.000. Its shape, when surrounded by its capsule, is convex anteriorly, and nearly plane posteriorly—*plano-convex*.

With regard to the two latter humors, the vitreous and aqueous, it is worthy of notice that they are not rendered turbid or opaque, as the crystalline is, by contact with foreign bodies; and this, indeed, is a most favourable circumstance, for otherwise, operations which interfere with the internal structure of the eye, such as the one before alluded to, would be impracticable, since we could not introduce an instrument into the organ without coming in contact with one of these humors. As it is, we are in the constant habit of introducing various slender instruments for the removal of cataract, and for other purposes, generally without in the slightest degree affecting the transparency of these delicate structures; whereas the slightest prick or puncture of the crystalline, or its capsule, is followed by almost immediate and permanent opacity. They possess another advantage over the last-named body in being capable of regeneration when removed; so that if a portion of the vitreous humor escapes from accident, or in an operation, the eye is none the worse: so also with the aqueous humor, it may be removed frequently, and will be renewed in a very few hours. Not so, however, with the crystalline: when once removed, it is never renovated,* and its place can only be supplied, and that imperfectly, by a double convex lens of glass, worn before the eye.

It is difficult to say why the more fluid and delicate parts of the eye should be comparatively unsusceptible of taking on diseased action, but such is the fact. For the vitreous humor very rarely exhibits an appearance of opacity, and the aqueous still less so, whilst the crystalline is very frequently so affected. Perhaps it is in proportion to their lesser or greater amount of vitality. We can hardly consider the water which enters into the composition of these various textures, particularly in the aqueous humor, as anything more than a secretion, and as possessing blood-vessels of its own.

---

* The very few instances on record of the contrary do not invalidate the correctness of this general statement.

We may further notice the advantage we derive from the humors being, not only transparent, but *colourless.* Without this condition the utility of the eye would be much lessened, since we should be unable properly to distinguish the colours of any object. That such would be the case, any one may satisfy himself by looking through stained glass; this will be found to lend to all objects its own tints. Thus, in whatever way we regard these beautiful structures, it is impossible not to perceive that they exhibit the most unquestionable marks of an intelligence of a far different and higher order than is observed in the feeble works of man.

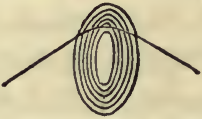
Another circumstance, worthy of our especial admiration, is the varying density of the different humors, and the gradual manner in which it is effected, as well as the way in which this arrangement promotes the excellence of the eye as an optical instrument. This has been very ably and clearly pointed out by that distinguished physiologist Sir Charles Bell, to whose opinions and views we shall often have to refer in the succeeding pages.

We cannot do better than quote his own recently published language.

"When we look upon the optician's lens, however perfect its polish may be, we can see its convex surface; that is to say, the rays of light which strike upon that surface do not all penetrate it, but are in part reflected to our eye, which is the occasion of our seeing it. We do not see the surface of the cornea of the human eye. Here, then, is an obvious superiority, since it implies that all the rays of light which strike the cornea enter it and are refracted, and none are returned to our eye. If we take the optician's lens between our fingers and hold it under water, we can no longer see it, however transparent the water. The reason of this is, that the rays of light are reflected when entering from a rare medium into a denser, more abundantly in proportion to the difference of the density. When the ray of light has penetrated the water, it also penetrates the glass, because there is not that difference of density between the water and the glass which there is between the atmosphere and the glass. From this we may estimate the importance of the surface of the cornea being moistened by the tears; for, however thinly the water may be spread over the surface of the eye, it is sufficient to make those rays that would otherwise be reflected penetrate the cornea.

" The whole humors of the eye are constituted with a regard to this law. There is nowhere an abrupt transition from a rare to a dense humor. The ray is transmitted from the cornea into the aqueous humor, and through that humor into the lens or crystalline humor. Were this latter humor uniform and of the density of its central part throughout, the ray would be in part reflected back from its surface. But it is not uniform, like a mass of glass: it consists of concentric layers, increasing in density from the surface to the centre. If we first look at the entire lens, and then take off its concentric layers, we shall see the surface of the internal nucleus more distinctly than the exterior and natural surface. The reason is obvious: the nucleus is so much more dense than the atmosphere that the reflection of the rays from it is more abundant. We now comprehend how finely it is provided that the crystalline lens should be surrounded with the *liquor Morgagnii,* a fluid which is but in a slight degree more dense than the aqueous humor.

The exterior surface of the lens itself is only a little more dense than the surrounding fluid, and each successive layer, from the surface to the centre, is of gradually increasing density: so that if we were to describe the course of the ray, it would not, as we see in the ordinary diagrams, pass like a straight line of the pen, but in a curved line, showing the gradual manner in which the ray is refracted through successive transparent layers. As it enters in the anterior half of its passage it encounters media of increasing density; but as it passes out behind, it is transmitted through media diminishing in density. The ray is nowhere opposed by that sudden increase of density which gives a disposition to reflection; and it passes through the vitreous humor still refracted, the density of that humor having a just correspondence with the posterior surface of the lens. We thus see the obvious superiority in the structure of the eye to anything that can be composed of glass, which is of uniform



[Refraction of light through the crystalline humor.]

density throughout, and must therefore present a succession of surfaces where rare and dense media are abruptly opposed to the rays transmitted."*

It is thus evident that the more closely we search into the formation of the structures of the eye, the more palpable are the marks we find of the agency of a supreme intelligence, and the stronger will be our reasons for believing that it is a perfect contrivance, and that it requires none of the cumbersome machinery, which opticians find necessary, to adapt their instruments to varying circumstances. Nor can we too much admire it in this respect, so perfectly is it suited to the situation in which we exist. It has been remarked, that if the eye had been so contrived that we could behold objects at vast distances only, and see them of their real dimensions, such as the planetary orbs, what a formidable and tremendous spectacle they would have presented. Or, on the other hand, if it had been so formed that we could see the minute and invisible animalcules, myriads of which pervade every drop of water, and occupy every blade of grass, and perhaps every portion of the atmosphere, as they appear through a powerful microscope, we should be alarmed, and perhaps disgusted, at the prospect. But, as the eye is neither a telescope nor a microscope, but a peculiar and matchless combination of each, we are placed in that happy medium best suited to our wants, in which objects are represented to us in those proportions only in which they are most serviceable to those wants.* Doubtless, had it been intended for us to view only the distant bodies which are placed in the immensity of space, the eye would have been provided with lenses suitable for distant objects only; or, if it had been designed for us to see those objects alone which immediately surround us, we should have been provided with lenses suitable only for near objects, such as are found in all the lower grades of beings. As it is, we are so happily constituted in these respects, the lenses of our eyes are so nicely constructed, that we are suited pretty accurately, as much so at least as our situation requires, to both near and distant objects. And having it in our power to discover by artificial contrivances, such as the telescope and the microscope, the vast and the diminutive objects of creation, we have ample reason to admire and rejoice at the position we are permitted to occupy in the scale of creation, with just so much of the heavens opened to our view as to stimulate us to aim at obtaining a more enlarged and comprehensive knowledge of them, and with quite enough of this earth and its inhabitants and products, to enable us to perceive that our wants and pleasures have been amply provided for by the great Father of all.

---

* Paley's Natural Theology. Appendix by Sir C. Bell, vol. ii., p. 334.

---

* This provision is abundantly manifest in the formation of the eyes of the minutest creatures; for we cannot but perceive that there is an entire agreement between their size and condition and the apparent magnitude of other bodies. Thus Leuwenhöeck and others have ascertained, by microscopic experiments on insects, that all objects are represented in their eyes with strict relation to the size of the creatures themselves, *e.g.*, the steeple of a church appearing no larger than the point of a fine needle!

CHAPTER V.

Of the Refractive Powers of Artificial Lenses and those of the Eye—The Nature and Properties of Light, &c.

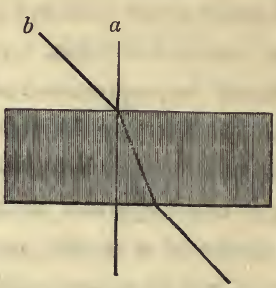
After the description, in the last chapter, of the humors of the eye, we shall now be prepared to perceive the manner in which they are useful in producing images.

These images are formed by means of light. There must, therefore, be a precise relation between the properties of light and the construction of the lenses or humors of the eye. And such we find really to be the case, for those humors are so formed and arranged within the eye, that they act upon light in a manner resembling the lenses of the optician, namely, by refracting it.

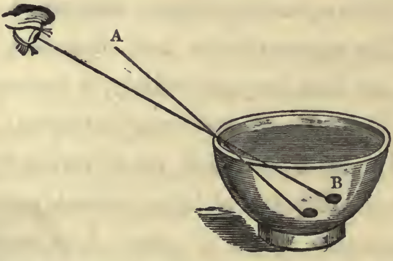
We have before remarked that images may be produced artificially by various contrivances, such as the camera obscura. In this instrument the chief agent in the production of the image is a piece of glass, ground into the shape, or nearly so, of the crystalline lens—a double convex lens. But any transparent substance will produce a similar effect, under proper circumstances, even atmospheric air; for if a small aperture be made in a window-shutter, and a piece of white paper held at a short distance from it, in the inside of a room, a picture of the objects outside will be represented on the paper. In like manner, if the lens be removed from a camera obscura and its place occupied by any substance having a small aperture in its centre, an image of the flame of a candle, or other object held up before it, will be noticed on the screen behind. This is the simplest way in which images can be produced, when light is permitted to pass through the transparent medium which is chosen for the purpose.

In this passage of light through lenses it undergoes a certain change of direction, which is named *refraction.* When a ray of light is refracted, as in entering from a rarer to a denser medium, it is always towards the perpendicular, and, therefore, when it enters a medium perpendicularly, it passes straight through without any bending or refraction. This is intended to be explained in the following diagram.

a represents a ray of light passing perpendicularly through a piece of glass; *b* is another ray entering the same obliquely: the latter, on arriving at the edge of the glass, is bent towards the perpendicular, and on emerging at its lower edge, it is again refracted in the original direction. A very simple proof of this is observed in the common experiment of noticing the apparent difference in the position of a piece of coin when in atmospheric air and when seen through the medium of water. A shilling, when placed in a basin, may be so situated



[Refraction of light through glass.]



[Refraction of light illustrated by a piece of coin in a basin, its position as seen when in and out of water.]

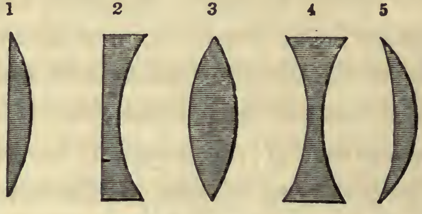
that the rim of the vessel may obstruct its view, but if water be added, it will be distinctly seen without its situation being at all changed.

Thus the ray of light from the coin will proceed in the direction A previous to the addition of the water, but when that fluid is poured into the vessel, the ray will be refracted down to the eye, and the shilling will appear to occupy the situation B.

The same appearance of bending is noticed when a stick is placed in water. And thus, too, if we look into the bed of a river, the pebbles appear to be raised in the water, and hence we suppose it to be much shallower than it really is. From this circumstance loss of life frequently results, from young persons being ignorant of this delusive appearance.

And it is precisely in this way that the humors of the eye are rendered available in refracting the rays of light when they pass through them. For this refraction takes place because of the different densities of the media through which the light traverses. And as the rays are refracted when passing from air into a denser medium, such as water or glass, so they are in like manner refracted when received into the eye. But in order to understand fully how the different humors affect the progress of light through them, it will be necessary briefly to notice the effect of glass lenses upon the rays.

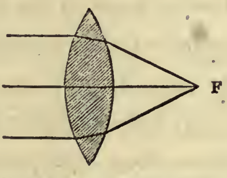
The term *lens* was originally employed to designate any transparent substance, which resembles in shape a flat bean or lentil. Its signification is not now, however, so restricted, for any transparent substance, partaking of any of the following forms, is called a lens. The first of these lenses, being plane on one side and convex on the other, is called *plano-convex;* the second is plane on one side and concave on the other, and is therefore called *plano-concave;* the third, being convex on both sides, is a *double-convex* lens; the fourth concave on both sides, *double-concave;* and the fifth, being convex on one side and concave on the other, if the concavity had been greater than the convexity, would have been called *concavo-convex,* but



[Various shaped lenses.]

the convexity being the greatest, it is termed a *meniscus.* A sphere or globe acts also as a powerful lens, and all the other lenses are but portions of a sphere.

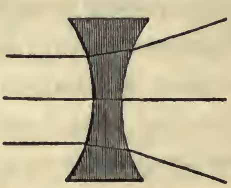
Bearing in mind what has been said, that a ray of light, passing perpendicularly through glass or water, is not refracted, but goes on in a straight line through its substance; and recollecting also that a ray of light passing obliquely is bent to the perpendicular, we see at once the direction in which the rays that pass through a double-convex lens would meet together at a given point beyond it. Thus, in the case of parallel rays falling on such a lens, the central ray, passing through the axis of the lens, will go on perpendicularly; whilst the lateral rays, passing obliquely, will be bent to the point F, which is called the focal point, from the term *focus,* which means the fire-place, because when light is converged by means of such a lens, it will set fire to a combustible substance.



[Refraction of parallel rays so as to converge them to a focus by means of a double-convex lens.]

The more convex a lens is formed, in the same proportion is its converging power increased, and the nearer will be its focus; and, on the other hand, the more nearly it approaches to a plane surface, will be the direction of the rays to the perpendicular, and the distance of the focus increased.

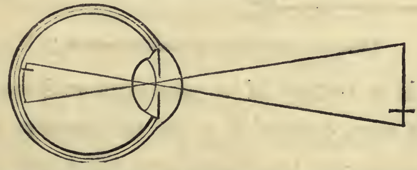
Again, rays of light passing through a double concave lens are also refracted, but in an opposite direction from those which pass through a convex lens, inasmuch as the curves are in an opposite direction. Thus parallel rays, after passing through such a lens, will go on diverging.



[Refraction of parallel rays so as to occasion divergence, by a double-concave lens.]

From what has been stated we shall readily perceive that the result of the combined action of the lenses upon the rays of light, as they pass to the bottom of the eye, is to produce an image of the object from which those rays proceed. Thus the convergence of the rays commencing in the aqueous humor is perfected in the crystalline; and then the vitreous humor, being less dense than the crystalline, and of a concave form, divergence takes place, and the rays are thrown upon the posterior part of the eye. In passing through the crystalline, the rays cross each other, so that those rays which pass from the lower part of an object are presented uppermost in the bottom of the eye, and the reverse; so that the images of objects are always inverted when received upon the retina.

These simple principles then, transferred to the eye, give us at once an insight into the manner in which pictures are formed in that organ.



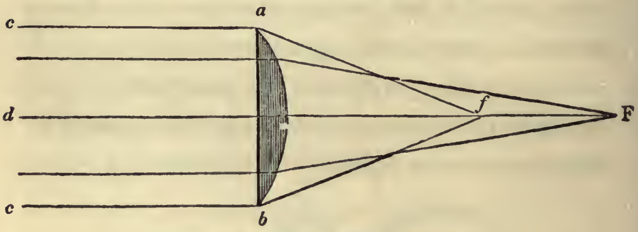
[The inverted image in the bottom of the eye upon the retina.]

We have before spoken of spherical and chromatic aberration, and have stated that the eye is free from both these imperfections,* and that they are noticed only in optical instruments.

---

* Dr. Wollaston has related an experiment by which he is supposed to have proved that the eye is not strictly achromatic; but it is not sensibly the reverse.

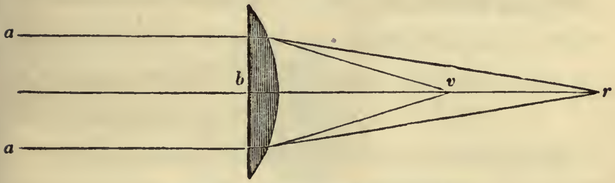
In speaking of the refracting power of a lens, it was stated that parallel rays falling upon its surface, at any point, would be all bent to one focus. This, however, is not strictly correct, for those rays which fall upon its margin or near to it, will be more refracted than those which pass through nearer its centre; and to this irregularity the term spherical aberration is applied.



[Diagram illustrating spherical aberration.]

a, b, is a section of a *plano-convex* lens. The extreme rays, marked *c, c,* are refracted to a point much nearer the lens than those which fall upon it near its centre. The ray passing through its centre, and in the axis of the lens, will go in a straight line *d*. The result is, that instead of one perfect image at F, there will be several images formed between that point and *f,* the place where the extreme rays meet; and hence a confused and imperfect representation of the object.

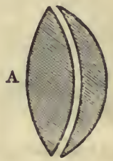
To illustrate the chromatic aberration, produced by a lens, let *a a* be pencils of white light proceeding from any luminous body, and falling on the lens *b;* these pencils will not be refracted colourless, but the red rays will cross the axis at *r,* and the violet rays will meet at *v;* and between those two points there will be a coloured spectrum of orange, yellow, green, and blue.



[Diagram illustrating chromatic aberration.]

Thus then we have an explanation of what is meant by chromatic aberration, or the dispersion of white light into a coloured spectrum, an effect which is observed in its passage through the various transparent media which are used in the formation of lenses.

But opticians have discovered that a *concave* lens of *flint* glass and a *convex* lens of *crown* glass, when placed in contact, will mutually correct each other, and that a pencil of white light, refracted by the compound lens, will remain colourless. In order, however, to have a complete correction of all the colours, more than two media must be used; and, therefore, the best telescopes have their object-lens composed of three kinds of glass. Sir John Herschell's object-glass is a double lens, the anterior glass A, or that which receives the incident ray, is an unequally convex lens of crown glass, the flatter side being placed outermost; the posterior glass is a meniscus of flint glass.



[Double lens in the object-glass of Sir John Herschell.]

On referring back to the lenses of the eye, and comparing them with the most perfect instruments that have yet been contrived, we are confirmed in the observation before made, that opticians should never lose sight of the arrangement of those lenses, and that the more they study and imitate the conformation and structure of those parts, the more nearly they will approach perfection.

On the other hand, we learn, from their investigations, that a certain degree of complexity in the lenses of the eye is necessary, in order to avoid those imperfections we have just noticed, which accompany the use of a single lens.

From all that we have said, in stating the properties of artificial lenses, it will be abundantly evident that the highest attainments of art approximate only to nature, and that the slow and almost painful progress of the human mind, after the lapse of centuries of investigation, has at length brought us, and that very imperfectly, to the formation of an instrument which is but an humble imitation of that model of optical skill, the eye.

In introducing a few observations on the probable nature and some of the properties of light, we shall have it in our power to add materially to the proofs of beneficence and design which are observed in its distribution and in its effects on other portions of animated nature.

Milton, who has made so many beautiful allusions to the eye and light, thus apostrophizes the latter,—

> "Hail! holy light, offspring of heaven, first-born," &c.

And truly, amongst the innumerable objects of beauty and utility by which we are everywhere surrounded, and throughout the wide domain of nature, there is none superior to that of light. Of beauty it is indeed the very essence, for the variegated appearance which everywhere meets the eye, when we survey the woods and fields, the sea and sky, and their various products and occupants, is all owing to the presence of light; and this not merely as the medium by which those objects are seen, but because they actually take possession of a portion of the light, attract it to themselves, and are literally clothed with its beauty. This sentiment has been thus elegantly expressed by Dr. Arnott:—

"The beauty is seen spread over a varied landscape, among the beds of the flower-gardens, on the spangled meads, in the plumage of birds, in the clouds around the rising and setting sun, in the circles of the rainbow. And the utility may be judged of by the reflection, that had man been compelled to supply his wants by groping in utter and unchangeable darkness, even if originally created with all the knowledge now existing in the world, he could scarcely have secured his existence for one day. Indeed, the earth without light would have been an unfit abode even for grubs, generated and living always amidst their food. Eternal night would have been universal death. Light, then, while the beauteous garb of nature, clothing the garden and the meadow,—glowing in the ruby, sparkling in the diamond,—is also the absolutely necessary medium of communication between living creatures and the universe around them." Again, "A man, wherever placed in light, receives by the eye from every object around,—from hill and tree, and even a single leaf,—nay, from every point in every object, and at every moment of time, a messenger of light to tell him what is there, and in what condition. Were he omnipresent, or had he the power of flitting from place to place with the speed of the wind, he could scarcely be more promptly informed."*

As respects the essential nature of light, two opposite theories are entertained: one is, that light is an extremely subtile, imponderable species of matter, an exquisitely refined, gaseous, or aeriform fluid; whilst the other presumes that light is but a property of matter, and that it is produced by vibrations or undulations, communicated by the oscillations of the sun to an extremely subtile fluid supposed to pervade all space, and to which the name ether is given.

---

* Elements of Physics, vol. ii. part 1, p. 163.

Sir Isaac Newton is the father of the material theory of light: he regarded light as consisting of minute particles or corpuscles, hence the term corpuscular has been applied to his theory; whilst the doctrine of undulations, or waves, was conceived by Huyghens, whose name it sometimes bears.

The undulæ are supposed to resemble those which are communicated to the air when sonorous bodies are struck. Sir Isaac Newton thought that the supposition of the ether, as also of its vibrations, may be maintained, whether light be a species, or only a property of matter, since the passage of light through the ether will probably occasion vibrations just the same as the sun beating against it is presumed to do; but he denied that the mere motion of the ether constitutes light.

The theory of waves has at least as many difficulties as the rival one, for it supposes the ether which cannot be shown to exist, as well as its undulæ, which cannot be demonstrated: whereas the vibrations of sonorous bodies produce a sensible change in the air, a fluid which indisputably exists. This theory farther supposes "that every point of a medium through which a ray of light passes is affected with a succession of periodical movements, regularly recurring at equal intervals, no less than five hundred millions of millions of times in a single second! that it is by such movements, communicated to the nerves of our eyes, that we see, nay, more, that it is the *difference* in the frequency of their recurrence which affects us with the sense of the diversity of colour; that, for instance, in acquiring the sensation of redness, our eyes are affected four hundred and eighty-two millions of millions of times; of yellowness, five hundred and forty-two millions of millions of times; and of violet, seven hundred and seven millions of millions of times per second!" These are the laborious calculations of the learned Dr. Thomas Young.

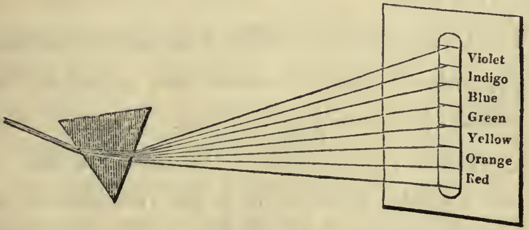
Whether light be material or otherwise, it travels with an amazing rapidity. It is calculated to arrive at this earth, in passing from the sun, in the space of about eight minutes, being at the rate of twelve millions of miles per minute. If we suppose light to be material, it must be subtile indeed, for although it moves with the inconceivable velocity mentioned, yet if it be concentrated by a lens and thrown upon the most delicate balance, it does not at all disturb its equilibrium; and this fact has been adduced as an argument against its materiality. It is difficult, however, to conceive why, if there be undulations, these should not likewise disturb the equilibrium, since vibrations of the air would produce that effect. The same answer is probably applicable to both cases, viz., that in the one the matter is so inconceivably delicate, that it is almost imponderable, and in the other the vibrations, being themselves imperceptible, produce no visible effect.

The divisibility of light into several coloured portions is justly regarded as a strong presumptive argument in favour of the materiality of light. Upon this point Sir John Herschell remarks:—"The hypothesis of Huyghens has not been fully successful in accounting for what may be considered the chief of all optical facts, the production of colours in the ordinary refraction of light by a prism, of which the theory of Newton gives a complete and elegant explanation; and the discovery of which by him marks one of the greatest epochs in the annals of experimental science. This, which has been often urged in objection to it, remains still, if not quite unanswered, at least only imperfectly removed."*

---

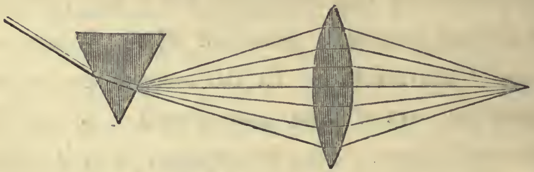
* Discourse on the Study of Natural Philosophy. Cabinet Cyclopædia, p. 251.

By passing a ray of light through a prism, Sir Isaac Newton found that although it entered the glass in a state of white or colourless light, yet after traversing that substance, and being received on a white ground, it presented all the various colours of the rainbow. In this manner he decomposed the rays of light, and proved it to be the source of colour. This decomposed light is called the *prismatic* or *solar spectrum,* and consists of seven different colours, viz., red, orange, yellow, green, blue, indigo, and violet, of which red is the least capable of being refracted, and violet the most so.



[Dispersion of the rays of light into the prismatic spectrum.]

The compound nature of light is also proved by a wheel having these various colours painted upon it in due proportion: if this be kept revolving, the colours will disappear, and a white circle only be seen. And the coloured rays, which have been separated by a prism, may again be collected by a lens, and white light reproduced.



[Convergence of the rays after separation by the prism.]

Sir David Brewster considers that there are in fact but three primitive colours, *red, yellow,* and *blue;* and Dr. Prout has conjectured that there are but two, *red* and *blue,* yellow being merely the resultant of these.

Thus we perceive that it is this property of divisibility which light possesses that produces the variation of colour which bodies present. One body attracts one portion of the rays, another attracts another portion, and the remainder are reflected; and thus we say that a particular body is of such a colour, because it reflects or throws off those particular rays, and absorbs the other coloured rays, which therefore do not appear. So that most substances in nature act as the prism does, by decomposing light into its various coloured rays, absorbing some of them and reflecting others. The exceptions to this law are in the case of some bodies which reflect all the rays, and these are called white, and others which absorb all and reflect none, and these are termed black.

The absorption of light by plants and animals, as well as its chemical action on minerals, is another circumstance which forcibly strikes the physiologist as an evidence of its materiality, since it is extremely difficult to conceive that mere vibrations can produce such effects upon all the three great divisions of natural bodies, as we know are brought about by its agency. On this point Sir David Brewster felicitously observes, " The colours of vegetable life and those of various kinds of solids arise from a specific attraction which the particles of those bodies exercise over the differently coloured rays of light. It is by the light of the sun that the coloured juices of plants are elaborated, that the colours of bodies are changed, and that many chemical combinations and decompositions are effected. It is not easy to allow that such effects can be produced by the mere vibration of an ethereal medium; and we are forced, by this class of facts, to reason as if light was material. When a portion of light enters a body, and is never seen again, we are entitled to say that it is detained by some power exerted over the light by the particles of the body. That it is attracted by the particles seems extremely probable, and that it enters into combination with them, and produces various chemical and physical effects, cannot well be doubted; and without knowing the manner in which this combination takes place, we may say that the light is *absorbed,* which is an accurate expression of the fact."* And Sir Charles Bell appositely remarks, "The supposition of light being the effect of the motion of an ether, does not fall in with our conceptions of the manner in which it enters into the composition of bodies, or influences chemical combinations, or affects the living powers of animals and vegetables."†

The absorption of some of the rays, and the reflection of others, we have before alluded to as the source of colour in bodies. And this constitutes not only a source of the highest pleasure to us, but is, moreover, of material benefit in aiding us to distinguish bodies from one another. Dr. Prout has indeed, in his Bridgewater Treatise, stated that all the pleasure we enjoy from this arrangement "is the gratuitous gift of the Creator, and places his benevolence in the strongest possible point of view. There was no reason why man should have distinguished colours at all, much less have been delighted with them." There is certainly no reason why it should lessen our admiration of the wisdom, power, and goodness of the Deity, because he has contrived that all the splendid colouring which produces so much delight should also be highly useful to us, as we certainly must suppose it to be. To say nothing of the dreary uniformity which the face of nature would everywhere present, what difficulty should we not experience in distinguishing objects from one another? Many animals and birds are scarcely discoverable when reposing in the grass and herbage of the field; and thus noxious beasts and reptiles are capable of pouncing upon their prey ere the latter are at all conscious of the presence of danger. Does not the soldier, when he wishes to escape the vigilant observation of the enemy, clothe himself in nature's prevailing colour, and amalgamate himself, as it were, with the vegetable world upon which he tramples?

---

* Treatise on Optics. Cabinet Cyclopædia, p. 284.

† Paley's Natural Theology, vol. ii. p. 328.

From these and many similar facts, then, we arrive at the conclusion that colours are not only pleasing and gratifying to the eye, but are really necessary to a proper discrimination of very many objects.

Upon the whole we cannot fail to perceive how highly valuable an agent light is in respect to our comforts, necessities, and enjoyments; and it is further apparent, not only that there is a strict relation between the organ of vision and the properties of light, but likewise that this important agent has a further beneficial influence upon almost all natural bodies, but more particularly and strikingly upon that extensive system of bodies which constitute the vegetable kingdom.

CHAPTER VI.

Of the Tunics or Coats of the Eye.

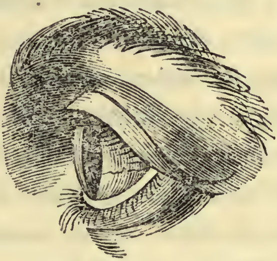
HAVING explained the manner in which the transparent media of the eye are useful, nay, essential, in the production of images; having noticed the phenomena which are observed in the passage of the rays of light through them, and contrasted them with those noticed in its passage through artificial lenses; and having shown the immeasurable superiority of the lenses of the eye, in every respect, we may now proceed to the consideration of the auxiliary portions of the organ.

We have already stated that the extreme delicacy of these transparent humors requires, for their adequate safeguard, that they should be carefully enclosed in some substance capable of giving them that protection, without which they could not exist. We notice the proceeding of the optician. No sooner has he prepared his lenses than he takes care to provide a suitable case for their reception, otherwise their brittleness would render them liable to numerous accidents which would render them unfit for the purposes he has destined them. Besides, they could not, without such a receptacle, have their proper relations at all maintained. The transparency and delicacy of glass lenses are infinitely beneath these properties of the humors of the eye. The aqueous humor, we have seen, is of the consistence of water; it is secreted and surrounded by its capsule, a membrane of such extreme tenuity as to be hardly discernible. How could such a texture long retain an existence, unless it were adequately protected? The mere pressure alone of the eye-lids would be amply sufficient to rupture it,—nay, a breath of air would destroy it. If we suppose it just strong enough to offer a resistance to such slight forces, still it would be liable to undergo a change of form, to undulate to and fro, from the most trivial causes; and all this would interfere with the passage of light through it, so that accurate vision would be next to impossible.

The vitreous humor is scarcely better defended: its tunic is so delicate that it is invisible when taken out of the eye, and so slender that the slightest force destroys it. The crystalline alone is capable of defence: its consistency and firmness preserve it from these dangers, but the least touch renders it opaque, and it is then entirely useless.

Hence it is essential that these slender and delicate textures should be well provided with means of defence. And for this purpose we see that they are surrounded and enclosed on all sides with a very tough, strong, and elastic capsule.

This capsule is divisible into two portions, an anterior and posterior. These two portions differ remarkably in a very essential point, the anterior being transparent, the posterior opaque. In this arrangement the strongest evidence of adaptation of means to an end unequivocally exists. The transparent anterior portion of the capsule, the *cornea*, is justly regarded as the window of the eye,



[The cornea or transparent front of the eye, through which is seen the iris or coloured portion; the sclerotica is the white of the eye, behind the cornea.]

and of course transparency constitutes the essential of such a contrivance.

In addition to the transparency of the cornea, its form may be considered as a very beautiful contrivance. As the cornea surrounds the anterior surface of the aqueous humor it necessarily partakes of its shape, which is convex. By this convexity of form it is enabled to collect rays of light from a great number of points without its position being in the slightest degree changed. If it were flat, or of a plane surface, what a remarkable contrast it would afford to the facility we now enjoy for an extensive range of vision, as a bow-window in a room, as every one must have experienced, affords us a more extensive prospect than a flat one.

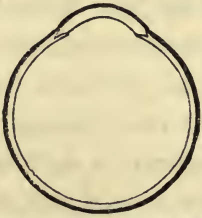
In addition to the utility derived from the form and transparency of the cornea, we may notice that derived from the density and firmness of its structure, which is fibro-cartilaginous, presenting a laminated appearance internally, the layers being numerous and placed upon each other somewhat like those of an onion, an arrangement which is well shown by trying to cut through its substance with scissors. Between these layers there is a cellular texture, containing a small quantity of transparent fluid, which after death becomes turbid and opaque. The cornea is so tough, and offers so much resistance, that it is difficult even to cut it. Hence we perceive the immense use it is of, from these combined advantages, in being rendered subservient to vision, and in protecting the internal structures of the eye, more especially the aqueous and crystalline humors and the iris, all of which lie immediately under it. So that, altogether, this structure, in point of transparency, form, and strength, stands pre-eminently unrivalled.

The opaque portion of the capsule, called the *sclerotic* coat, lies all round the lateral and posterior parts of the eye, and forms by far its largest portion. It forms five-sixths of the whole, the remaining sixth consisting of the cornea. Had it been continued round the whole eye it would have formed nearly a sphere. As it is, it constitutes a very large segment of a sphere, truncated anteriorly, for the reception of the cornea, which is fitted into it very much in the manner in which a watch-glass is fitted into its case. This aperture being not quite circular, but slightly elliptical, this is also the shape of the circumference of the cornea. By a long-continued maceration in water the cornea separates at this point from the sclerotica, a fact which substantiates the supposition that it is an entirely distinct texture. Their attachment, however, during life, is such that, but for their different appearance, we should be inclined to regard the one as a continuation of the other.

This attachment is effected by means of their blood-vessels interlacing with, and running into, one another. And here, perhaps, we remark as powerful a proof of the finger of Omnipotence as anywhere. The blood-vessels of the delicate cornea are, like the cornea itself, perfectly invisible during the state of health, nay, the blood itself, which passes through them, and which in other parts of the system is of a deep red or scarlet colour, and opaque, is here completely divested of colour and perfectly transparent. And so it must necessarily be for us to enjoy the faculty of vision; for if the eye become inflamed, and have red vessels shooting across the cornea, which is no uncommon occurrence, the sight is materially injured, if not absolutely destroyed. The like result is often brought about by opaque matter becoming deposited, by these enlarged vessels, into the substance of the cornea. Hence we perceive that the integrity of every minute portion of the organ is necessary to the perfection of the whole. How exquisitely, and with what matchless skill, is all this accomplished, in every atom which goes to make up the entire organ!

The cornea is convex, we have said, on its outer surface; it is more so than the sclerotica. Had the latter been continued in front of the eye, it would not have projected nearly so far as the cornea does, so that the latter forms a small segment of a smaller sphere than the sclerotica, a contrivance which adds to the convexity of the cornea, the advantages of which we have before hinted at.

The junction of the cornea with the sclerotica is usually effected by a contrivance somewhat resembling that termed *beveling.* On the outer side we observe the sclerotica overlaps the cornea more than it does internally, so that there is a greater



[Junction of the cornea and sclerotica.]

extent of the cornea on the inside than the outside of the anterior chamber, which is the name given to the space occupied by the aqueous humor.

The sclerotica, we have before remarked, is opaque; and it is of a bluish-white colour, as the common expression, the white of the eye, denotes. Now, it is quite as essential that the sclerotica should be opaque, as that the cornea should be transparent. It is essential for perfect vision that the posterior chamber should be dark, or at least not accessible to any light but what enters the pupil. In the formation of the sclerotica the same careful superintendence is manifest as in that of the cornea. The variation of structure is here as evidently a matter of design as we see in the telescope, where the optician renders the front of his instrument transparent, and the remainder of the tube opaque, and most completely so. To have made the sclerotica transparent would have been as absurd as to have attempted to construct a dark cell with walls of glass. Such aberrations as this are nowhere found in the works of nature.

The structure of the sclerotica is fibrous: it is very firm, extensile, and elastic, and hence it is well adapted for the defence of those fragile structures which it surrounds, such as the vitreous humor or the retina. Its density and firmness, however, are most remarkable at the posterior part of the eye-ball, where it is least of all exposed to danger. So that this increase of density must have relation to some other circumstance than the mere defence of the parts it surrounds; and, as it is found in all animals, there must undoubtedly be some general reason for such an uniform arrangement. The increased density of the sclerotica at the posterior part of the eye-ball seems to have reference to the number of vessels and nerves which penetrate it at this point, more particularly to the optic nerve, which is of so large a size, and which must be supported in some measure by this coat.

In opposition to the density of this coat at its posterior part, it is anteriorly much thinner, and indeed would be almost semi-transparent, were it not lined with the pigmentous matter, of which we shall soon have to give an account. Externally we find it presenting a rough surface just behind its point of junction with the cornea, and thus it is fitted for the insertion of the tendinous expansion of the muscles of the eye-ball; so obvious everywhere are the expressions of order and the indications of design.

The sclerotic coat is much denser in the eyes of fishes than in the eyes of those creatures which inhabit the surface of the earth. In a recent work we find the following note in explanation of the circumstance. "In viewing the structure of the eye as adjusted to the condition of fishes, we may remark the peculiar thickness of the sclerotic coat in the whale. Although he breathes the atmosphere, and lies out on the surface of the water, to escape his enemies he will plunge some hundred fathoms deep. The pressure therefore must be very great upon his surface, and on the surface of the eye. If a cork be knocked into the mouth of a bottle, so that it resists all further pressure that we can make upon it, and if this bottle be carried, by being attached to the sounding-lead, to a great depth in the sea, the pressure of the water will force in the cork and fill the bottle; for the cork is pressed with a force equal to the weight of the column of water above it, of which it is the base. It is pressed in all directions equally, so that a common-sized cork is reduced to the size of that of a phial bottle."*

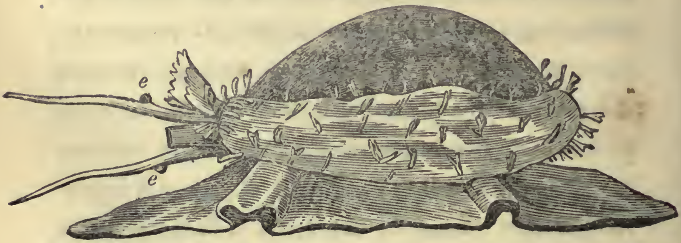
Further interesting information on this point has been obtained by the experiments of Captains Smyth and Beaufort, as related in Dr. Buckland's Bridgewater Treatise. Thus a copper cylinder, containing atmospheric air, was crushed flat under a pressure of three hundred fathoms. Bottles filled with air, or even water, when lowered to a similar depth, were usually burst; if they were returned whole, the corks were forced in, and their contents expelled and replaced by sea water.

---

* Paley's Natural Theology, new edition, by Lord Brougham and Sir C. Bell.

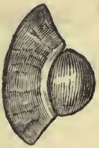
All this clearly demonstrates the amount of pressure to which bodies are subject at great distances below the surface of the ocean, and the care which it was necessary to bestow on the organization of the oceanic inhabitants to enable them to withstand it. It is manifest, however, that there can be no strict analogy between the condition of a bottle lowered into the sea and that of the eye. The cornea is not fitted into the sclerotica in the same manner that a cork is placed in the mouth of a bottle, but in such a way as to defy all pressure to force it. Neither is there any analogy between the texture of a glass bottle and that of the coats of the eye, the former being very brittle, whereas the coats of the eye are perfectly elastic. Of course the pressure cannot be disputed; it is the amount of it which seems to be exaggerated by the mode of stating the argument. Atmospheric air is elastic, and therefore, by pressure, may be reduced very considerably in its dimensions: so also the cork in the neck of the bottle. But water, we know, is almost inelastic, and will scarcely yield to pressure. The humors of the eye, we may safely presume, are similarly situated, and therefore not likely to yield to pressure.

In all orders of beings who possess vision there must necessarily exist some substance capable of containing and defending the humors, and at the same time of allowing the access of light to them anteriorly. Accordingly we find the tunics we have just described as found in man also existing in the lower grades of animals. They are of course much modified with regard to form, density, &c., but have always a strict relation to the circumstances of the animal. In the soft, fleshy, molluscous animals

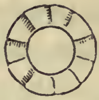


[*Cypræa tigres*, from the South Seas; *e*, *e*, the eyes placed upon the tentacula near their bases.]

the defensive covering partakes of the character of their bodies, and they are provided with the means of retracting the eyes, which are placed on the tentacula or feelers. In the articulata, as insects, the coverings of the eye are much firmer and of a horny consistence. In the crustacea, such as crabs, the eyes are set in short, bony cylinders. In some of these the cornea is formed simply by a portion of the skin which passes over the eye. In fishes, the cornea is almost flat, on account of the absence of the aqueous humor. In the amphibia it is slightly arched, and this convexity is infinitely increased in birds, in accordance with the quantity of aqueous humor and the corresponding size of the anterior chamber. The cornea is always more prominent in rapacious birds, whilst in aquatic birds it is much flatter. The sclerotica in birds consists of three different layers, the middle one of which is bone, and is composed of a number of plates, which are arranged all round the eye, lying close



[Bony plates at the anterior part of the sclerotica, proceeding to the margin of the cornea, in the eye of the hawk.]



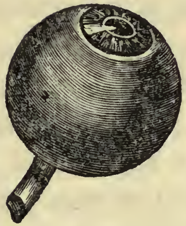
[Bony plates of the sclerotica.]

to and overlapping one another. Doubtless this is designed as an additional security for the defence of the organ against the sharp-pointed bills, which they have frequently to encounter in attacks upon each other, for the orbit itself is not sufficiently protective for this end. It can scarcely be intended, as some suppose, simply for the purpose of preserving the hemispherical form of the sclerotica, which is always regulated by the shape of the vitreous body.

In the higher animals the outer coverings of the eye are very similar to those of man: they differ in no essential point. There is always an aperture of considerable size in the posterior part of the sclerotica for the transmission of the optic nerve, as well as several smaller openings for the transmission of the other nerves and the vessels of the eye. Of these we have already spoken.

CHAPTER VII.

Of the Colouring Matter of the Eye, and its Membrane, the Choroid, &c.



[The sclerotica and cornea removed, showing the choroid membrane and the iris in front: the ciliary ligament is the white circle between these.]

When the optician has provided a receptacle for his lenses, he next proceeds to paint the whole of its internal surface perfectly black. He has learned, by experience, that if he fails to do so certain inconveniences result,—that there is a certain degree of reflection of the rays of light, which interferes with the perfection of the images formed by his lenses, and that other images are formed, irregularly, by these reflected rays.

Who would suppose, if not apprized of the fact, that the same proceeding is adopted in the eye? Yet such is strictly the case. For all around the internal concave surface of the sclerotic coat, we find a thin, delicate membrane in close contact with the strong outer tunic. This membrane is loaded with a dark-coloured secretion, having somewhat the appearance of Indian ink. It answers precisely the purpose of the paint which the optician introduces into his camera obscura or his telescope, and it is accordingly named *pigmentum nigrum,* when it is black, as it is in most animals, or *pigmentum fuscum,* when it is brown, as in the eye of man. This dark-coloured substance, then, absorbs those rays of light which would otherwise create confusion, and therefore disturb the perfection of vision, by their reflection in the interior of the organ.

The membrane which secretes this substance is called the *choroid.* Its structure is highly vascular, consisting of little more than a collection of blood-vessels, and these pour out this dark pigment. We have before observed that the blood is the source of all the secretions, that in one part of this system it produces the tears, in another the lenses, and here we find it the origin of the colouring matter which serves to darken the posterior chamber of the eye. We have likewise observed that these secretions are effected by a process of animal chemistry, of the nature of which we are almost or altogether ignorant.

In the lungs we know that the dark venous blood becomes converted into a bright scarlet, by being brought into contact with the oxygen of the air. How it becomes previously dark-red is unknown, but it is a question worthy of consideration. Why should the blood, which is returned from all parts of the body, and which is formed from the chyle, a colourless material, and which parts have themselves no colour but what they derive from the blood,—why should this fluid be so very dark-coloured, as it is found to be in the veins? May it not be owing to the absorption of light into the system? If we admit the absorption of that element by the choroid —and who can doubt it?—we must perceive that very large quantities of that subtile material must continually be, somehow or other, disposed of, or carried into the system by its vessels. The quantity must be great indeed, for we find the impressions of light to be gone almost instantly after the eye is closed. Much is also probably absorbed by the skin. Whether or not light, which is so plentifully absorbed in this way, has anything to do with the blackening of the blood or of the pigment, is a question of very difficult solution. It is certainly found that in the inhabitants of the torrid and frigid zones, where the light is more intense and powerful in its action, the pigment of the choroid is much thicker and darker than it is found to be in those who exist in the more temperate portions of the globe: we know also that light has a powerful influence in colouring the skin.

The colours of vegetables depend wholly upon the presence of light, for if they are removed out of its influence they become etiolated or bleached. Moreover, the chemical rays of light have been found to blacken certain salts, such as the white chloride of silver.

At present, however, we have not a sufficient number of facts upon which to form a theory, although there are enough to excite in us a belief that light is more or less concerned in the production of the colours of the eye, since it is so peculiarly under the influence of that agent, and since there is scarcely any other part of the system that possesses any colour at all, except what it derives from the blood. As the pigment is found to consist chiefly of carbon, it is of course affected by light much in the same manner as that substance is out of the animal economy.

Now, in the lungs we find a continual process going on which very much resembles that observed in the vessels of the choroid, except that in the one the blood is rendered of a brighter and in the other of a darker colour. In the respiratory organ the carbon of the blood is thrown off in the form of carbonic acid, and in return a supply of oxygen is received from the atmosphere. In the choroid a quantity of carbonaceous matter is deposited, which answers the double purpose of purifying the blood and of assisting towards perfecting the visual apparatus. In the former case oxygen is supposed to be absorbed, in the latter it is light that is taken into the system, and doubtless it has its uses in the animal as well as in the vegetable world. The peculiar colour which every substance in nature possesses is owing to the fact that every substance absorbs some of the rays of light and reflects others. By what law this is regulated, why some substances should absorb all the rays and others reflect all, and others, again, absorb some and reflect the rest, is at present unknown.

We have said that the choroid membrane is carried all round the internal concave surface of the sclerotic, or opaque portion of the capsule of the eye. It is of so fine a texture that it is evidently incapable of acting as a defence to the other parts of the organ, and its only use is the secretion and support of the pigment. Hence the impropriety is apparent of ranking it as one of the coats of the eye. It is very slightly attached to the sclerotica by loose cellular threads, and is composed of two laminæ, the outer very thin and highly vascular, the inner a cellular tissue in which the pigment is deposited. If the blood-vessels of the eye be injected, this membrane becomes one entire mass of the colouring matter employed, proving that it consists almost entirely of blood-vessels. The pigment seems to pervade its whole structure, and even stains the sclerotica with its dye, but is easily removed by maceration in water; and, if the maceration be continued for several days, the choroid becomes almost white, proving that it owes its colour solely to the existence of the pigment.

The colour of this membrane is not always brown or black. In the eyes of some animals it is variegated, and in this respect we observe also a beautiful and very striking adaptation of means to the wants of the different beings in whom this provision is found. This peculiar appearance of the choroid is seen in most quadrupeds, for, instead of the uniform dark stratum which exists in man, we find the back part of the choroid,—that on which the images are represented,—painted with the richest and most splendid tints, chiefly of purple, green, and gold; and this, most unquestionably, is designed for the purpose of reflecting light, and thus illuminating the images of objects when observed in the dark.

This contrivance is most remarkable in those animals which hunt their prey by night. We cannot fail to regard this provision otherwise than as an arrangement strikingly adapted to the habits and circumstances of those creatures, not only in their eyes possessing this property of reflecting light, but likewise in having the reflecting surface situated, as it is generally found to be, in the part of the eye upon which the images are represented, in the very neighbourhood of the optic nerve, and its termination in the retina.

In the inhabitants of the deep, even in the Cetacea,—for instance, the whale,—the choroid is found to be of a silvery white throughout, whilst the black pigment exists only in the ciliary processes, the portion of the choroid surrounding the crystalline humor, thus adapting them for the denser and darker medium in which they live. The *Albino,* who is entirely divested of this colouring matter, and therefore unfitted to see objects perfectly in broad daylight, can discern anything in the dark that to others would be perfectly invisible. Birds, on the other hand, being much exposed to light, have the pigment very dark, as in man.

So beautiful is this variegated membrane, so rich are the colours it exhibits, that it has been called, accordingly, the *tapetum* or carpet.

[The tapetum of animals.]

Those animals which are destined to be the prey of the larger quadrupeds, such as the rodentia,—rats and mice,—have the pigment dark throughout. So in man, who is not naturally a prowling animal, and who is able to procure artificial light, this pigment is always very dark when it exists; and by this means he is enabled to see better during the light of day. The only exception is the Albino, in whom, as we before remarked, there is a total absence of this colouring matter, whether in the eye, the hair, or the skin; and the consequence is, that he is unable to see distinctly in the broad glare of day, and prefers rambling about by the light of the moon, or even in the dark.

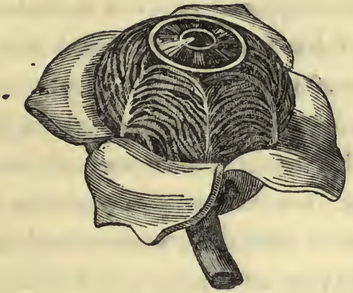
This dark secretion of the choroid has a considerable resemblance to the *rete mucosum*, the colouring matter in the skin of the negro, so that the pure blood of the white races is not altogether free from this supposed contaminating and degrading principle. When analyzed by the chemist it is found to consist chiefly of carbon and iron.

Around the entrance of the optic nerve, which perforates the choroid, as well as the sclerotica, there is an absence of the pigment; and at this point it is thought that the retina is insensible, or, at all events, that no image is formed, a condition which seems not to be properly understood.

The termination of the choroid anteriorly is just at the point where the sclerotica and cornea are connected together. At this point the membrane becomes altered in appearance, of a greyish-white colour, is attached very firmly to the sclerotica, taking on the character of a ligament, from whence it is called the iridian ligament, because it forms a fixed point for the action of the iris, as well as an attachment to the ~~choroid~~. sclerotica.

Before quitting the consideration of the choroid membrane, however, we must not omit noticing the beautiful appearance and the harmonious arrangement of its vessels. The name ciliary is applied to them, as it is to many of the delicate and minute structures of the eye, particularly those of the choroid and iris. There are two classes of ciliary arteries, one called the long ciliaries, which run between the sclerotica and choroid, and are distributed upon the iris; and another class, the short ciliaries, which pass into the choroid.

The veins have a very peculiar and beautiful arrangement: they have been likened to the weeping willow, the ciliary veins forming the trunks, and the *vena verticosa,* as they are called, representing the branches. When injected with colouring matter they have a most elegant appearance, and evince "a disposition indeed so accurate, so wonderfully distinct, and so constant, that there are few structures of the human body surpassing this in beauty, or more calculated to excite the admiration of the observer."*



[The vena verticosa and ciliary veins of the choroid, the sclerotica being turned down.]

A very peculiar process of this membrane, one met with only in the eyes of birds, is that to which the term *pecten* or *marsupium* is given. Its use is not properly understood. Various conjectures have been offered, none of which seems perfectly satisfactory. Its structure is precisely the same as that of the choroid, extremely vascular, and loaded with the black pigment. It passes from the choroid, near the entrance of the optic nerve, into the vitreous humor, in some instances reaching to the capsule of the crystalline lens, as in the vulture, parrot, turkey, goose, swan, &c.; whilst in others it only extends forwards two-thirds of the distance, and is attached to the cells of the membrane of the vitreous humor. (See fig. p. 53.)

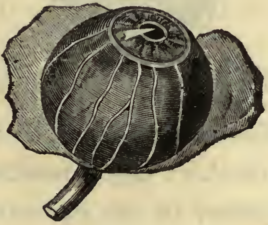
---

* Dalrymple, Anatomy of the Human Eye, 1834, p. 28.

Many have supposed that this structure is muscular, and it has been eagerly seized upon as evidence in proof of the power of adaptation to near and distant objects, because its function has been asserted to be that of pulling back the lens nearer to the retina; but this, at least, cannot be its office in those eyes in which it extends through only two-thirds of the vitreous humor, as is the case in those of the eagle and others.

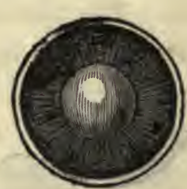
It can be regarded in no other light than as a collection of blood-vessels passing into the vitreous humor for its nourishment, and is apparently unconnected with the optical arrangements of the eye,—covered with black pigment, because so large a mass of vessels of the natural colour would have interfered with the perfection of vision, so striking in birds.

We may now proceed to notice another very elegant structure, which appears to be a continuation of the choroid membrane, although it differs from the latter in some respects, viz., the *ciliary body*. We have previously stated that the choroid terminates anteriorly in the ciliary or iridian ligament, which forms a portion of this ciliary body. The ciliary ligament passes all round the anterior portion of the eye-ball in the form of a zone or belt, its dimension in breadth being about a line and a half. It is denser, firmer, and of a lighter colour than the choroid, having no pigment deposited in its texture, at least on its outer aspect. At the point where the sclerotica and cornea unite there is a kind of groove expressly provided for the reception of this ligament, a circumstance which adds materially to its power of resistance. Externally, a very beautiful appearance is presented by the ciliary nerves running over this ligament, and between it and the capsule of the eye, in their passage to the iris. The plexiform appearance presented by this texture under the microscope is truly admirable.



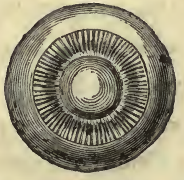
[The ciliary nerves running between the choroid and sclerotica to the iris]

Internally, the ciliary body has a very different aspect to that on its outer surface. On the inside it is quite dark, being copiously stained with the pigment, and appears to be directly continuous from the choroid. Instead of passing on to line the inner surface of the cornea, it is reflected directly in front of the vitreous humor to the margin of the crystalline, which it separates from the iris and aqueous humor. When seen posteriorly through the vitreous humor it presents a remarkable and very elegant appearance, which has been likened to the disc of a sun-flower. It is observed to be plaited with numerous folds, very much like what would be produced by plaiting black ribbon or silk. These folds are called the *ciliary processes,* and are computed to be about seventy or eighty in number: they extend, in radii, from the ciliary ligament to the circumference of the crystalline.



[The ciliary processes surrounding the crystalline lens.]

After these processes are separated from the membrane of the vitreous humor, and the pigment is washed off them, they look like greyish threads or fibres. Each alternate process is longer or shorter than the intermediate one. They are of a triangular shape, broader towards the ciliary ligament and finer near the crystalline. Little furrows, or indentations, are observed on the surface of the membrane of the vitreous humor, in which these fibres are deposited. These furrows are not stained with the pigment, but the spaces between them are, and thus an impression is left all round the front of the vitreous humor, which, when the processes are removed, leave a highly beautiful ring, called the ciliary zone, or the zone of Zinn, the latter term being applied to it from the name of the eminent anatomist who first described it.



[The ciliary zone, left after the removal of the ciliary processes upon the vitreous humor, the lens in situ.]

We may notice here that, under the ciliary zone, and between it and the membrane of the vitreous humor, surrounding the margin of the crystalline, a little canal is found, containing a minute quantity of watery fluid, which is called the canal of *Petit,* after its discoverer. By making an aperture and blowing into it, little bubbles of air will be observed as marking its situation.

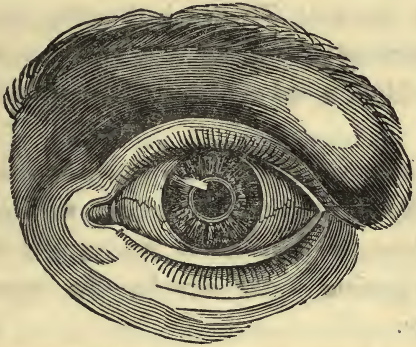
Now, it is impossible to contemplate the very striking and exquisite arrangement of the ciliary body and its processes without perceiving the admirable manner in which these slender and fragile structures are united with the contiguous parts. It was necessary to give support to the weight of the crystalline and vitreous bodies, to keep them from falling forwards against the iris, or into the aqueous humor; to effect this purpose we find the ciliary body placed immediately in front of the vitreous humor, and closely embracing the circumference of the crystalline; and then, to give power to the slender materials of which it is formed, we observe it so arranged, implanted in little furrows on the surface of the vitreous body, glued, as it were, to it, and adhering to it very firmly. We know that very slender and flimsy substances are strengthened by being plaited and matted together, as is observed in various productions in the arts; and, by the arrangement now contemplated, it is easy to see that a degree of strength and tenacity is given to this whole structure, which it could in no other way possess.

The texture of the ciliary body is cellular and vascular. Some have supposed it to be muscular, but there is not the slightest reason to believe that it possesses any motion. How, indeed, can the ciliary processes move? They are firmly adherent to the vitreous body, and in this respect are very unlike the iris, which is unadherent except at its ciliary margin, and is placed in the aqueous humor, where it can move about with the greatest freedom. Besides, if the ciliary processes pulled upon the circumference of the crystalline, it is not likely that they could influence either its shape or position. They are placed there to keep the humors in their proper position, and to prevent motion rather than to produce it. The notion of its muscularity springs from the theory of adaptation. To what improbable resources do we not fly to account for, or bolster up, a favourite hypothesis?

Thus, in the deep-seated, obscure, and more delicate parts of the eye, as well as in those which are grosser and more obvious, we observe the same marks of an evident relation between the purposes to be accomplished and the means employed to effect them.

CHAPTER VIII.

Of the Iris or Septum of the Eye.



[Front view of the eye—the iris, the coloured portion with the central opening, the pupil.]

To aid the more perfect refraction of the rays of light, and to cut off all those that are superfluous, we find a septum with a central aperture placed in front of the crystalline humor. From the variety of colours which are usually presented on its anterior surface, it is called the iris.

Abounding, as the eye does, in structures of the most exquisite beauty and of the most perfect contrivance, there is none perhaps superior, in either respect, to this splendid production. The others are for the most part hidden deep beneath the surface, and require skill and knowledge to bring them into view; but this is palpable and open to all, for we have only to look at the face of the individual in order to see it. To this the beaming eye owes its greatest attractions, and it is pre-eminently the source of beauty and of pleasure in the human face divine.

The iris commences at the anterior termination of the ciliary ligament, to which it is firmly attached, just behind the junction of the transparent and opaque portions of the capsule,—the cornea and sclerotica.

It passes immediately in front of the ciliary body, and between it and the aqueous humor, right across the globe of the eye, dividing it into two unequal chambers, the aqueous occupying the anterior chamber, and the other humors the posterior.

The iris may properly be regarded as a curtain or blind, for it shuts out all unnecessary light, and the manner in which it is opened and closed is truly admirable. Its shape is nearly circular, as is also that of its aperture. The point of its attachment, at the ciliary ligament, is called its ciliary margin, and its termination, in the central aperture, is called the pupillary margin, because the aperture itself is named the pupil. Although it is attached to the ciliary ligament, yet is it unconnected with the ciliary processes, or any other portion of the organ; hence it has considerable latitude, and can move to and from its circumference with the greatest freedom, a point of essential importance to the possession of accurate vision under all circumstances.

Now the aperture, the pupil, is placed very near the centre of the iris, but not precisely there. It inclines more to the inner angle of the eye, the side nearest the nose, and I have remarked that it is also placed rather above the centre: so that the iris is broader from the pupil to the outer angle than in the opposite direction, and it is also broader from the pupil to its most depending point than upwards. In both these respects there is an obvious intention; for, in the first place, it is necessary for the axes of the two eyes to correspond, and this is partly effected by bringing the pupils somewhat towards each other. It is quite apparent that if the pupils were placed contrariwise, they could not be so nicely directed towards the same points. Then, again, in the second place, as man is intended to walk erect, with his head elevated, the placing the pupil in the same direction is evidently in accordance with that design.

We sometimes find the iris described as an imperfect septum, and as being perforated in the centre. These are incorrect terms, for there is no imperfection, nor is there a perforation. There is an aperture, but so there is between the eye-lids. The only difference in the apertures is as regards size and figure, for they both resemble in another point, the variation in their dimensions under different circumstances.

It has been before stated that the iris moves freely in the aqueous humor. It is enabled to do so much more perfectly from the circumstance that this fluid is not placed merely in front of the iris, for a small portion is also found behind it, and between it and the crystalline lens, forming what is called the posterior chamber of the aqueous humor.

The texture of the iris is made up of three or four different laminæ, two of which, the posterior, are continued from the ciliary ligament, the anterior surface being the reflected membrane of the aqueous humor, and an intermediate substance, the proper tissue of the iris. The posterior layers, which are called the *uvea,* are continued from the choroid, and, like it, are furnished with a thick coat of pigment, so carefully is every substance in the interior of the eye, which is not perfectly pellucid, painted over with this dark absorbent substance. The colour of the uvea is quite independent of that of the anterior surface of the iris, for, whatever be the colour of the latter, the uvea is always brown, like the choroid.

The colouring matter observed on its anterior surface is, notwithstanding the different tints, a secretion from the blood-vessels of its structure, in like manner as that of the choroid is. It is not so easily removed as the latter, resembling in this respect the coloured portion of the choroid of animals, the tapetum. According to the prevailing colour of the anterior surface of the iris, we say of the individual he has such a coloured eye, as blue, grey, brown, &c.

Now the iris is, undoubtedly, a portion of the organ which contributes, in an eminent degree, to its perfection as an optical instrument. If we look downwards through the various orders of created beings, we find that, as soon as any appearance of complexity is observed, an iris is present. It is true in those animals in which it is first found, it is a much more simple contrivance than we observe it to be in the higher classes of animals and in man. In the cuttle-fish the iris is formed simply by the sclerotica, the outer covering of the eye, the pupil being covered over with the common integument, which is translucent and answers the purpose of a cornea.

[The iris of the cuttle-fish formed by the sclerotica reflected anteriorly, the pupil covered over by a thin transparent integument.]

In the eye of the scorpion the choroid is reflected over the anterior surface of the vitreous humor, so as to form there a sort of iris and pupil behind the crystalline. (See fig. p. 52.) In fishes, the iris is formed by the choroid becoming reflected anteriorly across the front of the eye, and almost in contact with the cornea. In them it is usually, like the choroid, of a gold or silver colour on its anterior surface: it is also motionless and very narrow, and the pupil, consequently, is of a uniformly large size, and it is also round. The same disposition is observed in the amphibia, in which creatures the pupil is usually round, and occasionally presents the appearance of a slight degree of motion, according to Carus, who observed it frequently in the frog. Albers also noticed slight mobility in the iris of the green turtle, evincing a gradual approximation to the more perfect eye of the superior classes.

Active and regular motion is first of all noticed in the iris of birds, and in them it is usually regarded as being under the direct agency of the will, more particularly among parrots. In this class the iris is found to have one or two layers continued from the choroid, as in man. The pupil is also round, with some exceptions. In the owl and other night birds the iris is generally very broad, to allow of a considerable expansion of the pupil in the dark.

Amongst quadrupeds there is but little difference from the iris of man. Its colour is usually darker than in birds, generally brown, sometimes yellow or green. Its breadth is greatest in the Rodentia, (rats, mice, &c.,) in which it is almost as extensive as the choroid. It is also much more so among Carnivorous than Herbivorous animals. In this respect, as amongst night-birds, it allows of a greater dilatation of the pupil, and is therefore in strict relation to their predatory habits. In the Rodentia, as well as in dogs, pigs, apes, and bats, the pupil is circular. In the Ruminants, as the ox, sheep, &c., it is transversely oval; and in the feline genus, as in the cat, perpendicularly oval. In all these circumstances we shall presently see an arrangement obviously suited to the exact conditions of the different creatures in which they are noticed.

The utility of the iris depends altogether upon its possessing the aperture in it called the pupil. It were better that it should be absent than be deficient in this respect, for this condition of it would render the whole eye utterly useless, since it is only through this aperture that light can get to the crystalline and vitreous humors in its passage to form the image upon the retina. The pupil, to a casual observer, appears like a black circular patch in the centre of the iris. It is black, because the choroid is so also, and allows of no reflection of light.

Now, in the eye of the fœtus this aperture is closed up. Its place is occupied by a thin membrane, which is called the pupillary membrane, and which disappears a short time before birth. This certainly affords a remarkable instance of a wise and provident arrangement. The child, before birth, has no occasion for light, and the pupil is closed over by a membrane. So soon as the period approaches for his emergence from darkness, this membrane becomes absorbed, and the consequence is that the light can pass through the pupillary aperture with every facility. The precise period when the membrane disappears is scarcely known. Probably it varies somewhat, for some authors state that it never disappears until after birth, whilst others have not discerned it after the sixth or seventh month of the fœtal life. A more striking instance of prospective wisdom and forethought than this can scarcely be adduced.

We have before remarked that the size of the aperture—the pupil—is liable to great variation. This is the case remarkably in birds, and in most of the higher animals, and in man; and this property is bestowed upon the iris by the addition of an apparatus of fibres of a most elaborate and finished construction. It is in the power of any one to observe this variation in the size of the pupil in the eye of another person. By exposing the eye to different degrees of light, as by turning it towards a candle or the window, and then looking away, it is distinctly manifest. In the stronger light the pupil diminishes, in the weaker it expands. We may observe the same in our own eyes with the aid of a looking-glass, by alternately shading them with the hand and removing it. Hence we perceive why the pupil is larger in the evening, which it always is, and in order to produce that change it is endowed with this sensibility to light and shade.

In the telescope we find a similar contrivance to the iris and the pupil. It is called, by opticians, the *diaphragm,* and answers precisely the purpose of the apparatus in the eye we are describing, particularly in fishes and other creatures, which do not possess any power of altering the dimensions of the pupil. But it is of course very inferior to the moveable iris, which has the power of contracting and dilating its aperture. If the iris did not possess this power of changing its dimensions, but were fixed, as it is in fishes, it would still be a very useful adjunct in aiding the general object of producing perfect images.

It is quite apparent from the general construction of the posterior chamber that a certain quantity of light only, just so much as is sufficient for the perfect formation of the images, is intended for admission into that part of the eye, and no more, because more would tend to confuse and weaken those images. The same design is perceptible in the formation of the iris: its substance perfectly opaque, its posterior surface coated with pigment, its central aperture for limiting the number of the rays, all point to this end.

If there were no iris,—if the whole of the crystalline were exposed to light, there would be too much illumination, more light would be admitted than is required, and the superfluous light would not be absorbed by the choroid, and thus a degree of reflection within the posterior chamber, and consequent confusion of vision, would be the result.

In fishes and animals which exist much in water, as the quantity of light is generally somewhat deficient, there is no need of defending them from an excess, and hence the pupil possesses no power of contracting itself; but, on the other hand, everything is contrived for increasing the supply of light, as is observed in the reflecting choroid and the widely dilated pupil.

In using artificial lenses, the cutting off, by means of a similar contrivance to the iris, those rays which would otherwise pass the circumference of the lens, has the effect of preventing spherical aberration.

But as this is provided for, in the eye, by the different consistency of the humors, we are scarcely entitled to regard the iris as likewise possessing the same office, although it may tend to the perfection of it. In a paper published in the "Records of General Science," vol. i., some account is given by me of certain experiments of this kind on an artificial eye, in which this was made evident. Near objects were proved also to be represented more perfectly with a small aperture than a large one, and *vice versâ.* However, to draw the inference that the iris is in the same way useful, subsequent observation on the eyes of animals soon after death has proved to be incorrect; for in those eyes both near and distant objects are represented with equal fidelity and correctness.

Another intention of the iris, and of its pupillary aperture, is to limit the field of view. It has been observed that there is a relation between the axis of the crystalline lens and that of the pupil, for the crystalline, as well as the pupil, is directed towards the inner angle of the eye. Now a very limited portion of the retina is generally employed in minute vision, and that portion corresponds with the axis of the eye. Although a more considerable part of the retina is probably occupied when an extensive landscape is contemplated, yet only a very small portion of the picture, at any one instant of time, comes under the more direct and immediate cognizance of the mind; and it is precisely that portion of it which corresponds with the visual axis. It appears certain, then, that by this contrivance, by cutting off superfluous rays, we are better enabled to pay that undivided attention to the minute points of an image, which is so necessary to examine it in all its details. In like manner we see that when the artist wishes to examine with great precision the individual points of his picture, he looks through a tube, which shall exclude all the other objects painted on his canvas, and give him the power of isolating the more particular portions of it, and of bestowing on them an exclusive attention.

The fact that a small hole in a window-shutter, without the presence of a lens, gives us an image of objects outside, proves that the pupillary aperture is a powerful and important accessory in the general arrangements of the eye. And if we look through a hole in a card or other substance, we perceive objects more distinctly. On the other hand, it is found that if the pupil be dilated artificially much beyond its average size, we shall lose this power of examining very minute or near objects with that perfect degree of accuracy which is otherwise attained, a certain degree of confusion being the result.

We observe considerable diversity in the ordinary size of the pupil in different individuals. In some it is always very small, and in others very large, and that without much affecting the accuracy of their vision. It is generally larger in children and young persons, and is usually found to be the most contracted in those who use the eyes very intently on minute, near, and brilliant objects, such as engravers, watchmakers, &c., a fact which would appear to indicate that there is a tendency in the pupil to contract under such circumstances. Indeed it is generally regarded that in looking at a distant object the pupil dilates more or less, and that in surveying near objects a certain degree of contraction takes place.

It is well known, too, that individuals who use their eyes much upon near objects are very apt to become short-sighted; and it has been thought by some that it is the contracted state of the pupil that is the cause of the defect in question, but it is very doubtful if it can justly be regarded as anything more than an accompaniment. Numerous individuals, certainly, have usually the pupils very small, and, notwithstanding, can see accurately at great distances; and, again, there are others who have large pupils, and yet are very near-sighted. This part of the subject, however, has been amply discussed in a prior chapter.

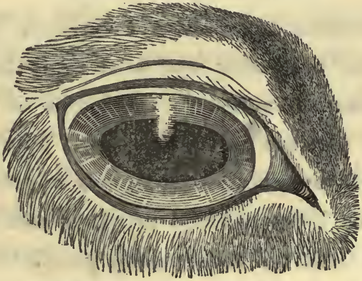
Why an eye that has been much used upon near or minute objects should undergo this change, we are not aware; but we know that there is a tendency observed in other parts of the body, that according as any part is used is the direction or growth of that part. So with the eye: if it be used excessively on very near or very distant objects, it becomes perfectly fitted only for one or the other. In a state of savage life these inconveniences are unknown, the eye being accustomed to an extensive range of vision. As men become civilized these defects are created, but with them the means of correcting them are also obtained. We have before spoken of adaptation to near and distant objects, and shall only remark here, that if this adapting power existed in the eye, there would be no such defects as near-sightedness or the reverse.

The power of changing the size of the pupil has, doubtless, been given for very useful and benevolent purposes. Generally speaking, the pupil, in the broad light of day, for the purposes before intimated, is somewhat contracted. The amount of contraction, we have said, varies according to the intensity of the light. Thus, if we sit in the shady part of a room, the pupil becomes somewhat expanded; but if we proceed to the window, and expose the eye to a stronger light, particularly to the direct rays of the sun, we find it immediately contracting to a small point.

How useful this varying size of the pupil is in the evening, when the light has more or less vanished, we may conceive from the fact that if a person, from internal disease, gets the pupil very much contracted and incapable of dilatation, he finds that he is almost blind in the dusk, although he has moderate vision in the day. So likewise with engravers and those who have the pupil much contracted, they are very liable to accidents in the evening, not seeing so well as others in a feeble light. It is well known, too, that the horse sees much better in the dark than his rider. In addition to the reflecting choroid, the tapetum, a principal reason is, because he has a very large and much dilated pupil. This expansion of the pupil allows of a much greater supply of light into the posterior chamber, and, consequently, tends to illuminate the faint images formed upon the retina, which would otherwise be imperceptible.

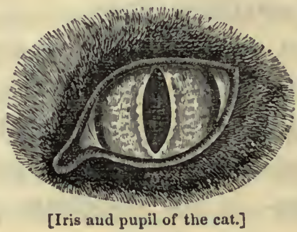
So uniform is this effect of light upon the iris, that persons who inhabit the snow-clad portions of the globe, we are informed, have their pupils much contracted, whilst the reverse is usually noticed in more watery and duller climes.

Not only is there a difference in the size of the pupil, but we also find a considerable variation in its shape. In man it is always circular, and most probably this form combines the greatest number of advantages. In the ruminating animals, and



[Iris and pupil of the sheep.]

some others, it is transversely oval. These have their heads much towards the ground, particularly in feeding, and the great breadth of the pupil will give them an extensive lateral view along the surface of the earth. In these animals, too, the eyes are placed on the sides of the head; and this direction of the pupils will tend to bring them nearer to a state of parallelism, in the same way as, in the human eye, the pupils being placed towards the inner angle, tends to bring the axis of each towards the other. In the feline genus, on the other hand, as we see in the cat, the pupil is perpendicularly oval, extending from above downwards, and, when contracted, appearing like a straight line. This conformation is suited to the habits of these animals, for they are not content with prowling along the ground, but occasionally spring to great heights, their heads being directed upwards, and their eyes placed in front and more nearly parallel.



[Iris and pupil of the cat.]

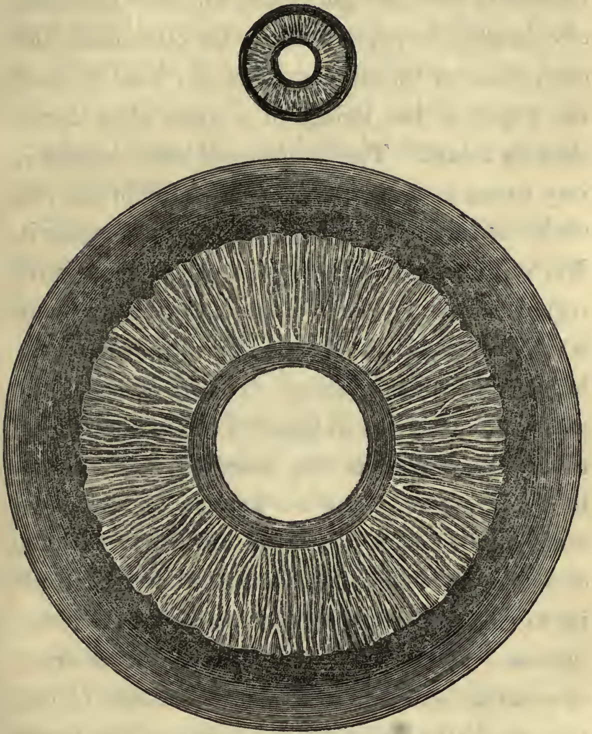
The colour of the iris varies in different individuals; and there is a certain relation established between the colour of that structure and that of the hair and skin. Thus in the Albino, whether man, beast, or bird, there is a total absence of the colouring matter, the hair and skin being of a perfect white, and the choroid and iris possessing no colour, except that imparted to it by the blood-vessels, which give it a reddish appearance. In the negro it is precisely the opposite, the hair, the skin, the choroid, the iris, are all exquisitely dark. The iris is so dark that it is almost impossible to distinguish between it and the pupil. The same condition is noticed in all the coloured races of mankind, and in those who are very dark-complexioned amongst the white races. In fair, light-complexioned individuals the colour of the hair is light and that of the iris blue or grey; and there are intermediate shades, such as green and yellow. Occasionally the iris of one eye is of a different colour from that of the other. One half, the upper, I have also known to be grey, and the other, the lower half, brown. These are varieties which are very uncommon, and may probably be the result of disease. But there is almost always a different shade, a greater or less intensity of colour, between the outer portion of the iris and that surrounding the pupil, particularly in light-coloured eyes. Sometimes I have noticed them of opposite colours; thus the outer portion has been light grey and the inner dark brown. Occasionally, too, large spots or patches of a deeper colour than the rest of the iris are observed.

A very remarkable appearance is often noticed on the surface of the iris. An irregular kind of ring or band is seen to run round it, not far from the pupil, and which separates the inner from the outer portion. This band is much lighter, often white, and consists of a number of segments of circles united together. The shape of these light-coloured fibres which form this band is sometimes such as to give an appearance remotely resembling the letters of the alphabet; and some very ingenious persons, and others very credulous, have persuaded themselves that they have been able to trace words written upon the iris. Thus a French child was some years ago exhibited in Paris, and afterwards brought over to England, in order that our countrymen, who are very fond of anything wonderful, might have an opportunity of reading the words "Napoleon Empereur" in the eyes of this favoured individual. Doubtless, it would require a considerable stretch of credulity to bring oneself to see these letters; but certainly the appearance in question is sometimes not a little remarkable.

An important question presents itself here. Much has been stated with regard to the faculty which in man, quadrupeds, and in birds, the iris possesses, of altering its dimensions very considerably. How is this accomplished? That it possesses this power is unquestionable: it is a matter of common observation. Much diversity of opinion, however, has prevailed, and still prevails, with regard to the kind of mechanism by which it is effected.

Now, the structure of the iris is so exquisitely delicate, its fibres so slender, and the whole apparatus on so diminutive a scale, that when we come to scrutinize its composition and nature, the result is somewhat similar to that of an investigation into the structure and laws which regulate the movements of aquatic animalcules. And we are compelled to adopt the same line of argument in considering the structure and functions of the iris, as we adopt in considering the structure and functions of those microscopic animals which are placed almost beyond the limits of observation.

It is not difficult, however, to observe two distinct orders of fibres in the structure of the iris: indeed their position may generally be seen on its outer surface, and is often remarkably distinct. When speaking of its various colours we observed that there is an irregular band which separates the pupillary from the outer portion of the iris. There can scarcely be a question but that this forms the boundary between the two orders of fibres. That we do not actually see the muscular fibres on the outer surface is, I think, quite clear, for they are covered over with the membrane of the aqueous humor, which is reflected upon it; with the colouring matter, which is secreted by the blood-vessels; and with the blood-vessels themselves, which appear to run in a somewhat different direction from that of the fibres. These fibres,—the muscular fibres, we will call them, by anticipation,—are most distinctly seen on the posterior surface of the iris, when the colouring matter is washed off. Then come into view two distinct sets of fibres; one, concentric, placed around the pupillary margin; the other, radiated, and proceeding from the former to the ciliary or outer margin. The radiated fibres are more distinct and more easily observed than the circular, which latter are exceedingly delicate and difficult of demonstration.



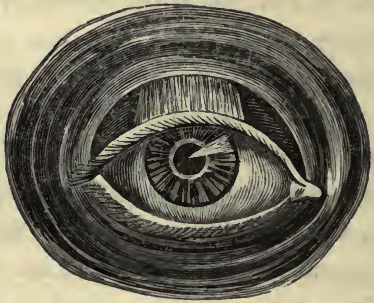
[The human iris, natural size, and magnified, showing the outer or radiated fibres and the inner or circular; the central aperture, the pupil.]

Now, it is clear that if these are muscular fibres, —if they have the power of contracting and relaxing themselves,—then the contraction of the radiated fibres will tend to draw the substance of the iris towards its outer margin, which will have the effect of enlarging the pupil; and, on the other hand, the contraction of the circular fibres will tend to close the pupil, as the strings of a purse when drawn close its mouth. The testimony of some authors is very strong in favour of the muscularity of the iris, whilst others are equally peremptory in denying it. Nor do I know that there is much to be said with regard to the influence of great names, for there is a pretty equal balance in that respect, particularly of the older authors. The moderns, on the whole, are decidedly in favour of the muscular doctrine. Mr. Lawrence has, indeed, remarked, that in the structure of the iris we may find what we are disposed to look for, either blood-vessels alone, or a mixture of muscular fibres with these, according to the view with which we commence the investigation. Hence there is ground for a variety of opinions as to the essential nature and kind of motion which the iris possesses. Accordingly, some regard it as depending merely upon elasticity; others think that the circular fibres are muscular and contract the pupil, whilst they regard the action of the radiated fibres as depending upon elasticity. But scarcely any one doubts that there are such fibres, the difference of opinion being as respects their peculiar action. Since it is so difficult, then, to demonstrate the actual muscularity of the iris, there is nothing left for us but to substantiate it, which, I think, may very fairly be done by analogy and deduction.

Now, the resemblance which the iris presents to muscular structures, in its varied actions, is most remarkable. If we regard the action of the circular fibres, which are placed concentrically around the pupil, we see that it must have a direct tendency to contract that aperture. That aperture, we find, does contract at various times.

In the lips, the eye-lids, and surrounding the various apertures of the body, we find similar structures, the same arrangement of fibres, which are as clear and indisputable as the parts themselves in which they are observed. In like manner as the pupil, so the mouth and eye-lids are contracted at various times, and by the action of these fibres.

Again, if we regard the straight, radiating fibres, which proceed towards the outer margin from the pupil, we perceive that their action will tend to expand that aperture. That aperture does expand itself at various times. In the same way the eye-lids and the mouth are supplied with radiating muscular fibres, proceeding from their apertures to some fixed point at a distance, and these fibres, beyond all question, open the eye-lids and the mouth.



[Muscles of the eye-lids. The circular or sphincter fibres surround both; those in the upper lid proceeding downwards from the levator muscle.]

The action of the muscular fibres of the eye-lids, and of those of the iris, corresponds in so many particulars, that the one seems to have been formed upon the model of, and intended to act with, the other. In a state of sleep, the sphincter (for so is called this circular arrangement of fibres) of the eye-lids is in action, and they are brought together and close over the eye. If we gently raise the upper lid of a sleeping person, we find a corresponding state of the iris, the pupil being exceedingly contracted. If we are a little too rough in our manipulation we shall perhaps awake the party into whose condition we have been thus curiously prying. If we do so, what follows? He opens his eye-lids wide, and stares at you, to ascertain the cause of the disturbance. And what of the pupil? Does that remain contracted, closed as nearly as it may be, during all this interruption? Truly not: it expands itself to the utmost, and lends its aid to the general design of obtaining intelligence.

In sleep, as we have said, the pupil is exceedingly contracted, but never entirely closes. And this is a very beautiful and wise arrangement. It is not intended that it ever should be actually closed, since there are no conditions that ever require such a state of the pupil. To inspect objects, it is always necessary to have some light, and the more illuminated the object, the less is the amount of light required. When inspecting a highly-illuminated object, the quantity of light need be but small, and therefore the pupil contracts to a small point; but if it were allowed to close, then the object would not be seen at all. Hence the iris is so constructed that the pupil never closes.

We have seen that there is a striking agreement between the condition of the eye-lids and that of the iris during sleep and at the period of waking. Now, we must consider the natural state of the eye-lids to be that of expansion when we are awake. There can be no doubt, too, but that a similar degree of expansion is also the natural condition of the pupil; but then we find it liable to be considerably modified by habit and other circumstances, as indeed we do the eye-lids also, for some persons close the lids much more than others.

In looking at distant or near objects, it is generally regarded that there is a certain correspondence between the degree of expansion and contraction of the eye-lids and of the iris. That there is likewise a correspondence between the direction of both, when looking upwards or downwards, is as certain as the necessity that exists for such an agreement; for it would be in vain that the pupil should be directed upwards if there was not the same direction of the upper eye-lid.

In most individuals there is observed a very rapid change in the size of the pupil,—it contracts and dilates itself with great rapidity when exposed to much variation in the intensity of the light. The same is remarked in the eye-lids,—the condition named winking. When the light is excessive, the pupil contracts and the eye-lids are closed; when it is moderated, both expand.

This correspondence of action is further maintained when the eye is suffering from disease. If a particle of dust get upon the eye, so much irritation is set up that both eye-lids and pupil become much contracted. If there be inflammation of the brain, the light, which would add to the mischief by disturbing that organ, is excluded in the same manner; whilst in cases of effusion of blood or water into the brain, sensation being almost destroyed, the pupils usually are much dilated, and the eye-lids are wide open. After death every one knows that the eye-lids remain open, and the pupil is similarly circumstanced.

It is very common, also, to find the eye-lids and the iris both in a state of paralysis together, from an affection of the nerves common to both. Such cases are of great frequency, many such having come under my own observation.

In certain experiments which were made by MAJENDIE, of dividing one of the nerves, the fifth, which is distributed to both these structures, he found that both were rendered motionless and inactive. Mr. Mayo, in his experiments on the third nerve, which is also common to both, produced the like result.

I have also observed a spasmodic condition of both these structures, the eye-lids being strongly contracted and quivering, and the pupil, at the same time, alternately contracting and partially dilating with great rapidity.

If we examine the eyes of the lower classes of beings, we notice a strict correspondence in the development of both, for we never find a moveable iris without the eye-lids being also present. Insects, mollusca, fishes, have neither. In some of the amphibia, traces have been observed of a slight degree of motion of the iris, very feeble, however; and at the same time the rudiments of eye-lids begin to show themselves. In birds are first found perfect eye-lids and a very active iris: the same condition is noticed in quadrupeds. In the latter, too, the existence of the pupillary membrane, which closes up that aperture before birth, and of a like membrane, which closes the aperture between the lids, affords another very striking analogy. Some animals, as dogs and cats, we know are born with the eye-lids closed: in these the pupil is also closed at birth, and both membranes disappear together.

"The iris, in birds," says CARUS, "is very delicate, but capable of active motion, to a certain extent voluntary, and corresponding to the action of the eye-lids. According to KEISER, even when the eye-lids are cut away, the contraction of the pupil accompanies every fruitless attempt to close them. Does not this consonance of motion in the eye-lids and iris, as well as the development of mobility in the latter at the same time with the first appearance of eye-lids, go far towards proving its muscularity?"*

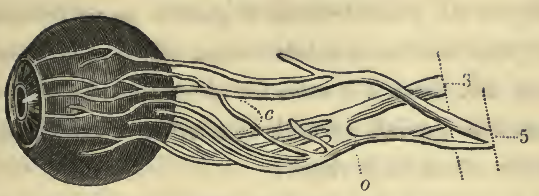
The points of resemblance between the iris and eye-lids are so numerous and so exact, that it is impossible to regard the former in any other light than as an internal eye-lid. In like manner as the eye-lids are well adapted to protect and defend the outer structures of the eye, so the iris is a sufficient safeguard to the more internal structures.

So much analogy,—so many points of agreement,—the similarity in arrangement of fibres,—the same actions,—the correspondence of these actions, during sleep and wakefulness, both in the state of health and in the morbid condition,—the same nervous supply,—the presence of mobility in each commencing at the same link in the animal creation,—the closure of each before birth by a similar membrane,—all lead to the irresistible conclusion that the iris is a muscular structure, that it is an internal eye-lid.

---

* Gore's Translation of Carus's Comparative Anatomy.

In this enumeration, if there be one point of agreement between the two structures which we have not sufficiently urged, it is that of the nervous supply. The iris is so amply supplied with nerves that but for the various actions and powers it possesses, we might regard them as profuse and even superfluous. In the orbit we observe two nerves, branches of which are distributed to the eye-lids, sending other branches which unite together and form a ganglion, and which, from its shape, is called the lenticular, or, from its office, the ophthalmic ganglion. After this union, numerous small nerves are seen to proceed from the ganglion, which are called the *ciliary* nerves; they are arranged in two fasciculi, and pass forwards to the globe of the eye, where they perforate the sclerotic coat and run between that membrane and the choroid, and finally are distributed upon the iris.



[*o*, the ophthalmic ganglion; 3, the third nerve; 5, the fifth nerve; *c*, the ciliary nerves.]

There cannot be a doubt but that these ciliary nerves possess properties similar to the original nerves from which they are derived, viz., the third and fifth. And one of the fasciculi, in all probability, is connected with one nerve, and the other with the remaining nerve.

With respect to one of these, the third nerve, which gives off the largest branch, it is so entirely, so indisputably a muscular nerve, for it supplies almost every muscle of the eye-ball, as well as one of the two muscles of the eye-lids, that we can in nowise imagine it to be anything but a muscular nerve; and, indeed, it is termed by anatomists *motor oculi,* showing that it has always been regarded as being, par excellence, the moving power of the eye. And why should it, then, be distributed to the iris, if the latter possess no muscular fibres?

If we refer to the eye-lids, between which and the iris we have observed so general an agreement, we find that one muscular nerve only is insufficient, and that there is a nerve for the fibres which separate the eye-lids, as well as another nerve for the fibres which close them.

Can we suppose, then, that the same nerve which enables the radiated fibres of the iris to expand the pupil, can also give to the circular fibres the power to contract that aperture? We can scarcely conceive that such is the case. Accordingly, as there are two sets of muscular fibres, those fibres having directly opposite actions, and therefore never acting in concert, but being antagonists to each other; and finding two different nerves sending branches to the iris, in which these different fibres are found; we seem irresistibly led to the conclusion, that one nerve presides over the action of one set of fibres, and that the other controls the motion of the antagonist fibres.

It must not be concealed, however, that it is very much the fashion to regard the branches of the fifth pair of nerves, all those at least which are expended upon the eye, as being simply nerves of sensation, as presiding over that exquisite sensibility which this organ possesses, and as having no control over its motions. I have already referred to the experiments of Majendie, as proving that, after division of the trunk of this nerve, a paralysis of the eyelids and of the iris was the result, these parts being entirely deprived of the power of motion. How such could be the case, and yet that nerve have no influence over the motions of these parts, is very difficult to understand.

It would be out of place here to enter into a long statement in support of my views on this point. I shall content myself with the following. There is a portion of the fifth nerve which every one allows to be muscular. It is distributed to the muscles of the jaw. Now, the motor nerves arise from a particular part of the brain: such is the case with the portion of the fifth, of which I am now speaking. Mr. SWAN, whose publications on the nerves have deservedly excited the greatest admiration, has traced some of the roots of the supposed merely sensitive portion of this nerve, and finds that they proceed from the same part of the brain as the motor portion. From this anatomical fact he observes, "it may be justly concluded, that if the anterior be a muscular nerve on account of its origin, part of the posterior (supposed merely sensitive) must be so likewise."*

From these and other reasons which might be adduced, I consider it highly probable that the fifth nerve has a motor power over the iris. Considering, moreover, as I do, the principle of antagonism to be quite as essential in the nerves as in the muscles, I cannot imagine that, in the animal body, the same nerve can control two muscles, which are directly opposite in their actions, any more than one general, or one leader, can direct the movements of two conflicting powers in the body politic. Until, then, it can be shown that a muscle can act without a nerve, or that a nerve can excite to action two antagonist muscles, we may fairly presume that, as in the iris there are two opposite actions, those actions are accomplished by two antagonist powers, through the agency of two independent nerves, and those nerves must be the third and fifth, or at least the branches derived from them. What modifying influence they may receive from their junction in the ganglion, and from their having a branch from the great sympathetic nerve,—the nerve of organic life,—is a matter of uncertainty. It is worthy of remark, too, that other branches are sent from the fifth to the iris, independently of those from the lenticular ganglion, and these may be the sentient branches merely, whilst the others may be presumed to regulate the motions of the iris.

---

* Demonstration of the Nerves. By Joseph Swan. 4to. London. 1834.

Another argument which helps to the conclusion we have arrived at, viz., that the branches from the fifth direct the action of the circular fibres, is, that the function of those from the third pair must necessarily be to dilate the pupil. And this may be proved in two ways; first, by the phenomena of sleep, and next by those observed in the waking condition. Now, I ask, is it at all reasonable to suppose that the closure of the pupil is effected through this nerve, when the condition of the eyelids, in sleep, proves that it is perfectly powerless at that period? In this state the eye-lids are closed, because the third nerve no longer acts, and they are abandoned to the care of the antagonist nerve, which directs the motion of their sphincter fibres. The muscles of the eye-ball are also in a state of repose, and there is no action going on except that of the sphincters,—those vigilant guardians which so carefully protect the organ when no other defence is provided. Is it possible, then, to conceive that the third nerve, when it has so evidently lost all control over every other part of the eye, can be acting with increased energy on the iris, as it must be if it be the nerve of the sphincter? This seems so contrary to reason, that we are compelled to abandon the conception as untenable.

The waking period equally proves this point. No sooner do we awake from sleep than the energies of the system are aroused. One of the most prominent and striking agents is the third nerve, which, as we have seen, has been asleep, and now awakes refreshed. On the instant, the upper lid is raised by the action of the muscle which this nerve superintends, and the muscles of the globe are likewise in motion. The pupil, we have seen, at the same moment expands by the action of the radiated fibres. Shall we commit so egregious an error as to say, that the moment the third nerve awakes and seizes the reins, by which it directs the muscles of the globe of the eye and the eye-lid, it that very moment abandons the iris and leaves the pupil to be directed by chance or some other power, as may be? In short, it is as unreasonable to suppose that this nerve is controlling the iris during sleep, as that it ceases to do so the instant of awaking.

The observance of the phenomena noticed at the instant we awake gives us an insight, at once, into the extensive powers which this nerve possesses over the eye. We observe the up-raised lid, the expanded pupil, the muscles of the globe directing it towards the axis of the other eye, all harmoniously combining towards one common end,—the perfecting of the means of obtaining intelligence through this organ. Can we, for a moment, doubt that all these phenomena, every one of which is essential to give complete utility to the others, are produced by the agency of that powerful nerve which controls so many of the motions of the eye?

There is still another point to be referred to, of exceeding weight, viz., the voluntary power which some individuals possess over the motions of the iris. That celebrated physiologist, Dr. Roget, who is endowed with this power in a remarkable degree, is capable of contracting or dilating the pupil, and has frequently effected these changes in the presence of individuals possessing great acumen, and not likely to be mistaken as to what they actually saw. "The effort of which I am conscious," says Dr. R., "when performing the voluntary contraction of the pupil, is the same as that which accompanies the adaptation of the eye to the vision of near objects, and is of course productive of an increase of its refractive power." . . . . . . "It is still more easy for me, while an object is placed near my eye and distinctly seen, immediately to relax the organ so as to fit it for the distinct vision of the most distant objects: and these changes I can effect in succession with considerable rapidity, each change being accompanied with a corresponding enlargement or diminution of the pupil."*

The late Mr. John Shaw, a gentleman of the highest professional attainments, has given an account of what he himself observed during one of these experiments by Dr. Roget. "I thought," says he, "I could perceive that the exertion which attended the attempt, had some effect upon the motions of the upper lid."†

Passing over the Doctor's observations about the adjustment of the eye, the effort of which he expresses himself conscious is undoubtedly a muscular one, and that effort is made in order that the axis of the eye may be directed to a point either nearer or more remote than before. I believe that the real way in which the will exerts this power over the iris, is by associating the action of its fibres with that of those of the eye-lids. I have myself made many experiments of this kind, nor do I think that very much practice is required to perform them satisfactorily. In attempting to dilate the pupil I put the fibres of the levator muscle of the upper lid into strong action, and an expansion of the pupil follows, proportionate to the degree of exertion employed by the levator. In attempting to contract the pupil, it is effected by exciting a similar degree of action in the orbicular or sphincter fibres of the lids. And these are the actions, I have no doubt, which are excited by Dr. Roget, although he does not express himself in precisely the same terms; and, in confirmation of this view, I may again refer to the expression of Mr. Shaw, just quoted.

---

* See Letter from Dr. Roget, published in Travers's Synopsis of Diseases of the Eye. Third edition, 1824, pp. 73, 74.

† Medico-Chirurgical Transactions, vol. xii., p. 120.

I have always found, with Dr. R., that it is much easier to dilate than to contract the pupil; and this strengthens my opinion, that the dilatation is effected by the agency of the third nerve, the most powerful and the most important muscular nerve of the eye.

Some physiologists have concluded that the third nerve presides over the sphincter fibres of the iris, from noticing that when there is a paralysis of that nerve, these fibres are relaxed and the pupil is dilated. The truth is, that the pupil is liable to considerable variation in size under these circumstances. I have seen it sometimes very small, and at others a good deal dilated; but then we observe as great a difference in the healthy state.

Now, we have remarked at great length upon the numerous points of agreement between the actions of the fibres of the eye-lids and those of the iris. There are some points of difference, however, which also require notice, and which may assist us in explaining this variety in the size of the pupil in the case in question.

We have seen that in sleep the pupil and the eye-lids are both contracted, and that when we awake both immediately expand. When, however, we begin to exercise the organ, the expansion of the pupil usually diminishes, and we find the fissure between the lids much larger, relatively as well as actually, than the pupillary aperture. This difference is undoubtedly necessary for the purposes of vision, for the eye-lids must remain open to allow of the free motion of the eye-ball in every direction, whilst a large expansion of the pupil would be somewhat unfavourable to perfect vision under all circumstances. So that when we are engaged in the contemplation of surrounding objects, there is usually a considerable difference in the relative degree of expansion of the two apertures. In the eye-lids the straight fibres are found to have the mastery over those of the sphincter, by which means the upper lid is elevated. The sphincter fibres are, indeed, continually striving to overcome the superior energy of their antagonists, as we see in the continual winking motions of the lids; but, nevertheless, the advantage they obtain is so trifling that it only lasts an instant of time,—the twinkling of an eye,—a very beautiful contrivance, of which more hereafter.

In the iris, just the reverse of this generally happens: here we have the sphincter fibres (modified, to be sure, by the habits and occupations of individuals) possessing a decided preponderance of power over their antagonist fibres, so that the prevailing tendency of its aperture is to contract, although there is an almost continual change in its dimensions, analogous to the winking motions of the eye-lids.

In the healthy condition, then, the two sets of fibres are in a state of continual action, one set counteracting the other, those of the eye-lids having a tendency to expand the aperture, those of the iris tending rather to contract it.

But the balance of power may be destroyed:—suppose one set of fibres to be paralyzed, what is the condition of the other? It may be thought that when one set becomes paralyzed, the other will be roused to increased energy, but such will not be the case; for whichever set is rendered motionless, its antagonist will fall into a quiet, inactive state. If the levator muscle of the upper lid become paralyzed, the lid is observed to be drooping, and has no power of raising itself, but it is in a quiet, passive condition. So if the sphincter of the eye-lids be rendered motionless, there is no active condition of the antagonist, the eye is not staring, wide open, with the lid raised to the utmost extent, but it is in a passive, quiescent state, and raised by the mechanical position of the levator muscle.

How stands the case with regard to the iris? The pupil is not contracted when the radiated fibres are paralyzed, nor has it the active, mobile state which I have compared to the winking motions of the lids. On the contrary, the sphincter, having lost the counterpoise of its antagonist, ceases to perform its function; its prevailing tendency, that of contraction, is suspended; it becomes relaxed, and the consequence is, that the pupil is more or less dilated, and the amount of dilatation will probably be decided by the habitually contracted or dilated condition of that aperture.

If we admit that the prevailing tendency of the pupil is to contract, we immediately infer that if the circular fibres cease to act, a certain degree of relaxation of those fibres will be the result, and a somewhat dilated pupil the necessary consequence.

Moreover, if we examine the actual arrangement and disposition of the fibres of which the iris is composed, we observe a striking contrast between them and those of the eye-lids. The orbicular fibres of the latter are attached to the skin and various other firm points, and are unconnected with the fibres of the antagonist muscle. In this respect, how very different is the condition of the iris. The sphincter fibres have no independent connexions, they have nothing but water in front and behind them, and have no support but what they derive from their antagonist fibres, and with these they are so interlaced and mixed up that they can have no other point of attachment. From this arrangement it will be evident that the changes of the pupil must depend upon the conjoint action of both sets of fibres, the one alternately yielding to and opposing the other. So that if the action of the radiated fibres becomes paralyzed, how is it possible that that of the circular fibres can continue? The balance of power is destroyed, the sphincter cannot act because the radiated fibres are inert, motionless, and incapable of giving any support; they have nothing else upon which to act, and the result is that they are perfectly passive. Hence we see that a paralysis of the radiated is equivalent to the same condition of the sphincter fibres. And it is thus that I would explain the circumstance, that when the radiated fibres are paralyzed, as I contend they are by disease of the third nerve, the pupil is usually more or less dilated. That there are cases in which there is no dilatation I know, for I have observed such, and I attribute it to the circumstance of the pupil being habitually very much contracted and perhaps fixed in such persons.

Some physiologists regard the iris as not being subject to the laws which regulate such structures as the eye-lids, &c.,—as being placed under the control of what are termed the nerves of organic life,—as being regulated by the ganglionic system of nerves; and they consider the nerves of the iris, not as receiving branches from the third and fifth pairs, but rather that the latter are merely connected with the former. But the fact, before noticed, that paralysis of the third and fifth nerves is always accompanied by a paralytic condition of the iris, is a sufficient refutation of such an hypothesis. Another fact, which is generally known, viz., that certain narcotic vegetables, such as belladonna, paralyze the sphincter of the iris by being applied to the eye-brows and eye-lids, parts which are profusely supplied with branches of the fifth nerve, is an additional proof that the iris is under the influence of that nerve. Injuries of the branches of this nerve on the forehead are also, as is well ascertained, frequently followed by paralysis of the iris.

On the whole it seems utterly impossible to attribute the various movements of the iris to any other property than muscularity, directly influenced by its proper nerves, the third and fifth, these modified in some way perhaps by their union in the lenticular ganglion, and by their connexion with the great sympathetic nerve.

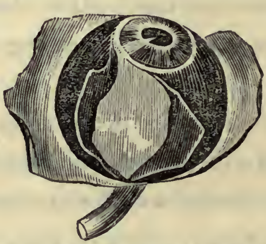
In the eyes of the larger animals the fibres of the iris are more distinct than in man; but if they were actually invisible, such invisibility could not be regarded as a satisfactory proof of their non-existence. What myriads of living and moving beings are there in which it is impossible to trace any, the slightest, appearance of muscular fibres! But whether following their thousand movements with the naked eye, or by means of the microscope, can we for a moment hesitate, upon the powerful impulse of analogy, to attribute them to muscular action?

How nicely, with what beautiful adaptation and perfect accuracy, must the fibres of the iris be arranged,—those fibres which, almost invisible, in whatever direction they act, always preserve an exact identity in the shape of the pupil; for we invariably find that, whether it be widely dilated, or contracted to the smallest possible point, it always retains the most perfect rotundity of form. Where is the contrivance that can produce effects such as we have indicated, other than that whose structure we have been endeavouring thus feebly to describe?

Thus, whatever portion of the organ we examine, we there meet with overwhelming proofs of superhuman wisdom, and of a skill and contrivance every way beyond the puny efforts of man, and with evidences of design, order, and beneficence; nowhere, however, are these more forcibly and clearly demonstrated than in the arrangement and varied actions of the delicate structure we have just been contemplating.

CHAPTER IX.

Of the Means by which Information of the Images is conveyed to the Brain—The Retina and Optic Nerve.



[The sclerotica and choroid reflected to show the retina beneath,—the vitreous humor shining through—the optic nerve entering below.]

In the preceding chapters we have been describing a very highly-finished model of an optical apparatus. We have described the lenses; the outer case, designed for their reception; the pigment, spread over the inner surface of that case; and, lastly, the septum, with its central aperture. These form the different parts of which every telescope or camera obscura consists.

But in an apparatus contributing to sensation, something more is required than what we notice in an inanimate optical instrument. It is manifest that it would be to very little purpose that all the parts, which we have thus amply described, were formed, arranged, and placed with strict relation to each other, in the manner pointed out, if it were not that some means were likewise contrived whereby impressions made upon the delicate mechanism of the eye may be conveyed to the brain.

It is quite evident that this could be effectually accomplished only by some medium connected with the instrument of vision on the one hand, and with the sentient organ on the other. Now, the only known media of this description in the animal economy are those fine, slender, and delicate fibrils called nerves. The nerves, then, are the media by which impressions are conveyed to the brain. How, or in what manner, they do this is a perfect mystery; for of the nature of the process by which a knowledge of the images formed in the bottom of the eye is carried to that organ, we cannot even imagine. If the nerve which traverses the space between the eye and the brain were a transparent tube, we might fancy it to be a telescope, conveying a view of the landscape, or other scene represented in the eye, into the interior of the brain. The optic nerve, however, is not transparent, nor is it a tube. It is a solid body, similar to a cord, consisting of an infinite number of small fibrils or threads, bound up together in one common bundle, and connected with the posterior part of the eye-ball at one extremity, and with the interior of the brain at the other.

"The optic nerve," says Sir D. Brewster, "is the channel by which the mind peruses the handwriting of nature on the retina, and through which it transfers to that material tablet its decisions and its creations." And this is all that we can say on the matter.

We only know that images must be formed upon the expanded nerve, the retina, and that those images must be very perfect, otherwise either no information, or very imperfect information, respecting the objects they represent can be received by the brain. Thus if the rays of light, proceeding from any object, do not come to a focus at precisely the same part of the eye, viz., at the retina, no knowledge of that object can possibly arrive at the seat of intelligence, and we shall remain in utter ignorance of its nature and qualities. And this appears to be a formidable objection to the theory of vibrations, for the mere action of light upon the retina is not sufficient,—there must be a perfect and very accurate picture of the object represented upon that membrane: *e. g.*, if a near-sighted person look at an object placed at a distance, he obtains not the requisite information regarding it, because the position of the retina is not precisely in accordance with the conformation of the lenses of the eye, and not because there is a want of light to strike upon the retina.

Now, it is very certain that it is the retina and optic nerve which are the agents employed for communicating the knowledge received by the eye to the brain. For if either become diseased, or the particular portion of the brain with which they are connected, this process is interrupted and vision is destroyed. This is a fact so well authenticated, that it cannot be questioned. Hence it was a matter of the utmost astonishment to the scientific world when a celebrated French physiologist put the question, is the optic really the nerve of vision? We shall have occasion, hereafter, to refer to M. Majendie's experiments, and those results which led him to entertain such a question, and shall therefore not dwell on the subject in this stage of our inquiry.

This provision of a nervous membrane, for the reception of the images formed by the passage of light through the lenses, and that of the nervous cord which proceeds from the former to the brain, can be regarded in no other light than as an instance of that all-pervading principle of perfect adaptation of means to an end, of a wise and benevolent arrangement. If a child were to be born with the whole eye perfect in all its optical details, and this nervous membrane were absent, or the optic nerve wanting, he might just as well have no eye at all. The position the retina occupies in the eye is equally illustrative of this point. It is placed at the precise part where the images can be most perfectly formed, at the back of the posterior chamber of the eye, and between the vitreous humor and the choroid membrane. This is the focal point, where alone the images can be perfect, and accordingly at this point is the retina placed to receive those images. And this supposes not merely the proper position of the retina, but also a corresponding perfect arrangement of every part of which the eye-ball is made up.

The mind becomes filled with astonishment when we duly contemplate the fact, that we actually *see* the images which are thus represented on the nervous membrane of the eye; so truly wonderful are the phenomena which constitute sight, so much is expressed in the term beyond what we can even conceive of it. A very little reflection proves that vision does not take place in the eye, where the image is represented, but that it is in the sensorium that this surprising faculty is completed and perfected, and that the eye is merely the instrument or outward organ of vision. There must necessarily therefore be an organ within the brain, in which this faculty is properly developed, and of which indeed we are constantly speaking as the mind's eye. This, we are sure, must be the case, from the observation of numerous facts; for, first, a disease of a given portion of the brain is productive of blindness, whilst the eye and optic nerve remain perfectly healthy; and, second, we have the power of internal vision when we are actually asleep; and it is known also that spectral illusions, and other similar phenomena, are perceived by persons who have lost their eyes, and that these persons possess the power of conjuring up the figures and forms of numerous objects with which they had been familiar previous to the loss of their vision.

Sight, indeed, may strictly be regarded as a phenomenon, not of the material frame-work, but of the mind. We cannot possibly imagine that any substance can be endowed with that faculty solely by the agency of matter. No one thinks of disputing that a stone cannot see, or that if it were provided with an apparatus to procure images, it would still be insensible to their existence. So the orbit of living man, an optical instrument placed in it, without the existence of that essential, immaterial principle which we call the mind, could no-how produce vision. Sight is, indeed, one of those wonderful and inscrutable essences which, like the nature of the mind itself, is enwrapped in impenetrable mystery, and of which the mind knows nothing, any more than it does of its own intrinsic nature; for the mind can no more become acquainted with itself or scrutinize its own nature, than matter can examine the properties of matter, —than a lens can perceive the picture which it produces. The mind is so constituted that it may take cognizance of material substances, and many of their properties; but, with respect to its own nature, it can form no satisfactory conception.

The composition of the brain and of the optic nerves, fine as that composition is, is infinitely too gross to render them anything more than the material agents through which the mind, and through which vision,—one of its properties,—is manifested. And thus we are enabled, from the contemplation of this faculty alone, to perceive that something more than mere material agency is requisite for sensation, and perception, and intelligence;—that there is a principle superadded to the material organization, which, in the brain, gives perception and thought, vision and feeling, and all the other modifications of sensation which are exercised and made manifest through the different organs of the senses. And it is this development of mind, through the material organization, that gives to man what he possesses of the divine nature; and hence the fire which sparkles in the eye, the animation which lights up the human countenance, the commanding dignity of form, and the god-like and erect attitude of his whole bearing.

We have stated that the retina is the fine, nervous structure which is placed in the posterior chamber of the eye for the reception of the images formed by the lenses, and that it is expanded upon, and therefore concentric to, the choroid membrane, and placed between it and the vitreous humor. After the optic nerve has perforated the outer case of the eye, as well as the choroid membrane, it terminates abruptly in a conical eminence, or papilla, from which the retina appears to be expanded, at first thicker and firmer, and gradually becoming thinner and finer, until it terminates anteriorly at the ciliary body.

The manner in which the optic nerve passes through the outer coat of the eye is worthy of attention. There is not a single aperture for the passage of the entire nerve, but its substance is divided into a great number of filaments, and these separately perforate the sclerotic coat, which is here much thicker and firmer than at its anterior aspect. And this tends to confirm the view before expressed, that this firmer condition of the sclerotica was bestowed as a protection or defence to the nerves and vessels in their passage through it. We see that if so large a nerve as the optic had passed through such a structure as the eye-ball, in a single cord, it would have been difficult to have given it sufficient support; but by splitting itself into a hundred different parts, and each part perforating the sclerotica separately and adhering to it in its passage, such a degree of support is given to the whole as would otherwise not have been attained.

The optic nerve penetrates the eye-ball, not precisely in the centre or the axis of the eye, but a little on one side, towards the nose. It is generally supposed that at this point the retina, or rather the extremity of the optic nerve, is not sensible. A certain experiment is related which appears to corroborate this supposition. If three wafers be placed on a sheet of white paper, in a horizontal line, at intervals of two inches, and the eye be directed to the one nearest the nose, the middle wafer will not be seen, although the other two will be distinctly visible. One eye only must be used in making the experiment.

Now, as the optic nerves enter the eye laterally, and not in the axis of vision, no deficiency, it is said, is observed, for the same object cannot be represented over this point in both eyes. Dr. Paley has remarked upon this, "The difference which this makes is, that no part of an object is unperceived by both eyes at the same time." If the inference were correct, that a portion of the retina is insensible, it would follow that a person who has only one eye will not be able to perceive some portion of an object at which he is looking,—a circumstance which is not observed. The truth is, that there is no practical result from the alleged insensibility of this particular point, and nothing but the ingenious experiment alluded to gives a plausible appearance to the supposition.

The retina is unadherent to either of the surfaces with which it is in contact, being simply placed between them. It is perfectly transparent during life, but becomes opaque very soon after death, or when affected with disease; and, if it were not transparent during life, it is evident that it would not accord with the design exhibited in the distribution of the choroid membrane behind it. The painted membrane is placed there for absorbing the rays of light, and if the retina were an opaque body, those rays could not penetrate the retina, and therefore could not be absorbed by the choroid.

A small foramen or depression in the retina is usually described as being situated on the outer side of the entrance of the optic nerve; and is called the *foramen centrale.* Its supposed site corresponds to the axis of the eye, and hence it has been regarded as of some importance; but recent investigations render it extremely doubtful if it be anything but a delusive appearance, which exists only after death.*

The portion of the retina which corresponds with the axis of the eye is usually regarded as being more sensible than the rest of it. Undoubtedly there is a general sensibility over the whole of the retina, by which we perceive the outline of a great number of objects; but if we fix the eye upon any one object, or any particular part of an object, the image of each separate portion successively must be traced upon that part of the retina in the axis of the eye. Whether this superior sensibility be owing to this portion of the retina being more employed, or an original property, is a matter of conjecture.

The substance of the retina is divisible into a medullary, or nervous, and a vascular structure; the former is extremely delicate and pulpy, and is surrounded by the latter, which encloses it in two filmy structures, the innermost of which, from its vascularity, is called *tunica vasculosa,* and the outermost *tunica Jacobi,* from its discoverer, Dr. Jacob. The vascular texture seems to be composed almost exclusively of blood-vessels, branches of the central artery of the retina, which supplies the nervous structure with blood, and which also branches off into the vitreous humor. This, as we have remarked in regard to another structure, affords us at once a proof that the blood is essential to the nutrition of all parts of the system, and that it is changed from its peculiar and usual character of a red, highly-coloured, opaque fluid, to one perfectly colourless and pellucid. The same is observed also with regard to the minute vessels which convey the nutrient principle, so that they in nowise interfere with the process of vision, which they would do but for this provision.

---

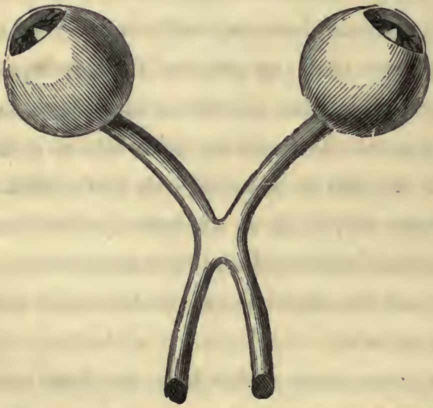
* Vide Dalrymple, op. cit. Appendix.

The retina is so essential to vision that it is always found in all grades of animals which possess this faculty. Nor is there any striking variation in the manner in which it is distributed in the interior of the organ, at least in the more perfect creatures.

The optic nerve itself, in the mode in which it traverses the orbit, affords a beautiful example of the adaptation that exists between the various parts of this system, for we observe that it runs in a zig-zag, tortuous direction as it approaches the eye-ball. It seems very clear that, but for this arrangement, on the one hand the movements of the eye-ball would be much restrained, and, on the other, supposing those motions to exist as they now do, the optic nerve itself would be very liable to too much extension, which would probably interfere with the important function to which it is subservient.

The large size of the optic nerve seems to indicate its great importance, for it is observed to be a general law, that the greater the development of the nervous system, the more important and the more perfect the functions with which it is associated. In size it is second only to the fifth nerve, that nerve which is so extensively distributed to every part of the head and face, and without whose agency all the other nerves of the senses would be almost useless.

The great care with which the optic nerve is protected leads to similar conclusions. It is embedded in a soft, fatty cushion, which during life, and in the temperature of the animal body, is an oily fluid, and therefore well calculated to admit of the movement of the nerve with that of the eye-ball. The manner in which it is surrounded by the muscles of the eye-ball affords, if necessary, an additional safeguard. Its immediate investment or sheath is continued from the membranes of the brain; whilst in the orbit it is also defended by that strong, bony cavity, at the posterior part of which is an aperture, a canal, or tunnel, which perforates the base of the skull for the transmission of the nerve to the brain. Having passed through



[Junction of the two optic nerves within the cranium.]

this opening it unites with its fellow from the opposite eye, and thus tends to combine the impressions received by the two separate nerves; and having thus, as it were, compared the intelligence received by each, they pass, one on each side, to their final destination in the brain.

CHAPTER X.

Of the Moving Powers of the Eye—Its Muscles and their Nerves.

We have now reached the point at which we find an optical instrument, endowed with the faculty of obtaining images, and of communicating those images to the brain.

Having arrived thus far, we perceive that we are still very distant from the perfect mechanism which the eye in reality is. We have nothing yet but a motionless eye-ball and a medium of connexion with the sensorium.

If we reflect for a moment upon what our condition would be in this state of things, we shall perceive how infinitely multiplied are the sources of our gratification and pleasure by the addition of a power which enables us to direct the eye to every conceivable point in space, and that almost without our knowledge of the fact, much less of any effort in the accomplishment of it.

Accustomed, as we are, to the incessant enjoyment of this advantage, it is scarcely possible for us to imagine the very limited benefit we should derive from the eye if deprived of it; nothing but the lamentable condition itself could demonstrate this fact. Such a condition, fortunately, is rarely or never witnessed, and could only exist from such extensive disease of the brain, that the individual would be utterly unconscious of it.

Sir Charles Bell has remarked that "whatever degree of admiration and eulogy we bestow upon the eye-ball and optic nerve, it is entirely misplaced if applied to these exclusively; since the high endowments of this organ belong to the exercise of the whole eye, to its exterior apparatus as much as to its humors and the proper nerve of vision." And certainly, vision once obtained, there is nothing adds more to the extended enjoyment of that faculty than the muscular apparatus with which it is provided; for by it we are enabled to direct the eye, as far as the limits of unaided vision will permit, in every possible direction and to every object in nature.

If we contemplate the movements of a telescope, the difficulty we have in directing it to any object, so as to obtain a view of it, we see at once the immeasurable superiority of the eye in this respect: the motions of this organ are effected with the utmost facility, and with so much speed, that we are hardly able to appreciate the exercise of any muscular effort.

If we confine ourselves to the smallest room, and reflect on the myriads of points towards which the eye can be directed with the most rapid succession, and can examine every minute variation in the regularity of its surface, we then obtain some idea of the advantages which we enjoy from the possession of this muscular apparatus: or in reading a page of letter-press, to how many points of its surface is the eye directed; every portion of each letter must be passed over in succession accurately and critically, in order that a due impression may be conveyed to the nervous structure and thence to the brain; and this could not be effected but by the agency of the muscles of the eye.

This impression on the retina must always be made on that particular portion which we have described as corresponding to the axis of vision. And in order to bring the images there, it is essential that the axis of the eye be directed immediately to the object, which it is by the muscles. We have before remarked on the correspondence between the axis of the pupil and that of the eye generally. No doubt the motions of the pupil take place with a strict relation to those of the eye-ball, and both are, to a considerable extent, under the same nervous influence.

The motion of the eye-ball, as contributory to the perfection of vision, has been beautifully illustrated by Sir C. Bell. He says, "There is a continual desire of exercising the sensible spot, the proper seat of vision. When an impression is made upon the retina, in that unsatisfactory degree which is the effect of its striking any part but the centre, there is an effort made to direct the axis towards it, or, in other words, to receive the rays from it upon the more sensible centre. It is this sensibility, therefore, conjoined with the action of the muscles of the eye-ball, which produces the constant searching motion of the eye; so that, in effect, from the lesser sensibility of the retina generally, arises the necessity for this exercise of the organ; and to this may be attributed its high perfections.

"Let us now see how essential this searching motion of the eye is to vision. On coming into a room we see the whole side of it at once,—the mirror, the pictures, the cornice, the chairs; but we are deceived; being unconscious of the motions of the eye, and that each object is rapidly, but successively presented to it. It is easy to show that if the eye were steady, vision would be quickly lost; that all those objects which are distinct and brilliant, are so from the motion of the eye; that they would disappear if it were otherwise. For example, let us fix the eye on one point, a thing difficult to do, owing to the very disposition to motion in the eye; but by repeated attempts we may at length acquire the power of fixing the eye to a point. When we have done so, we shall find that the whole scene becomes more and more obscure, and finally vanishes. Let us fix the eye on the corner of the frame of the principal picture in the room. At first, everything around it is distinct; in a very little time, however, the impression becomes weaker, objects appear dim, and then the eye has an almost uncontrollable desire to wander; if this be resisted, the impressions of the figures in the picture first fade; for a time we see the gilded frame, but this also becomes dim. When we have thus far ascertained the fact, if we change the direction of the eye but ever so little, at once the whole scene will be again perfect before us."*

This portion of the retina, corresponding with the axis of the eye, may be more sensible to images, because it is the part chiefly occupied. The mind can only be occupied, at any one instant, with one particular object, or part of an object. Hence it regards, at any one instant, only one particular portion of the picture impressed upon the retina. We know that the retina, like the mind, may have many objects presented to it generally, but can only be impressed by one object at once; so that there is a selection of that object presented to the axis, because that portion of the retina is more immediately directed to the object from whence the impression is received. Hence there is a continual desire, as Sir Charles expresses it, "of exercising the sensible spot, the proper seat of vision."

From all this it appears that a constant succession of pictures is necessary to keep up the due sensibility of the retina, and that either the nervous membrane becomes paralyzed from the constant repetition of the same, or the mind ceases to regard the impressions made upon it, and desires some new representation.

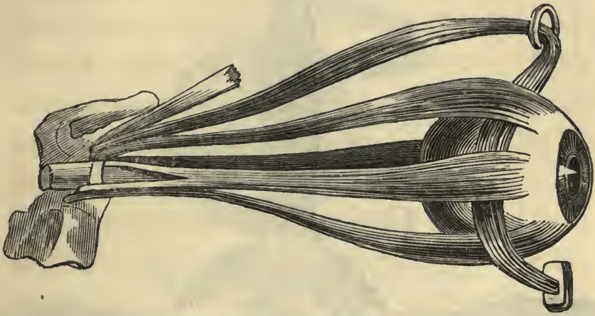
---

* Sir C. Bell's Bridgewater Treatise, pp. 315, 316.

Astronomers have observed that in looking at the fixed stars, the eye, after much exertion, frequently fails to detect the situation of some of those bodies; but that by directing it to an object known to be in the immediate vicinity, the missing body will be observed, and this by its image being thrown on a portion of the retina somewhat removed from the centre, whose sensibility has not been thus exhausted, showing that the centre is not exclusively sensible to the images of objects. I have noticed many individuals who have been permanently in this condition. A person thus situated, on directing his eyes to two bodies placed immediately before him, will not see that in the axis of the eye, but the one placed beside it.

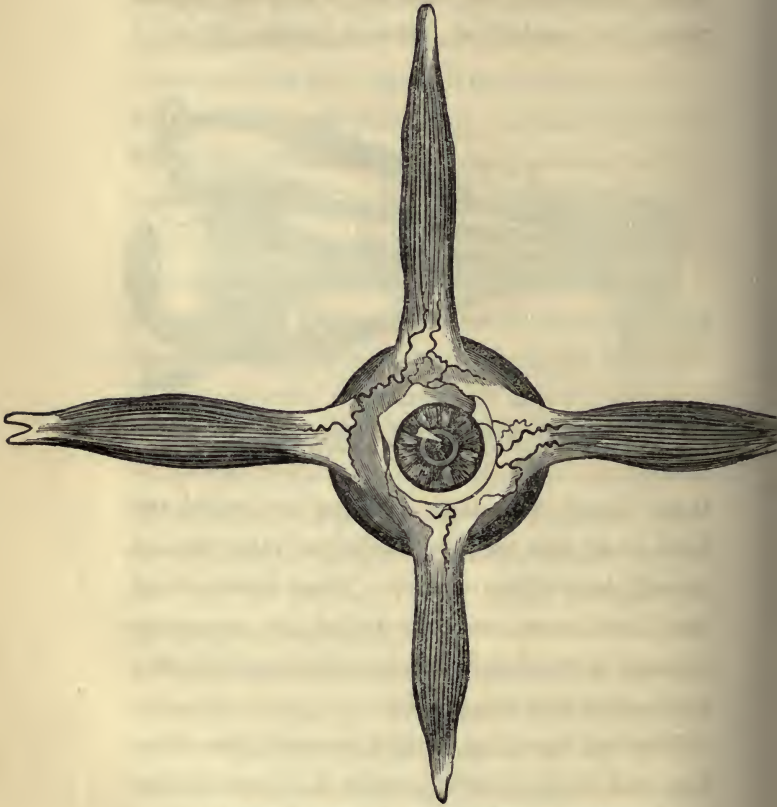
These observations tend to demonstrate the necessity that exists for this power of precisely and rapidly changing the direction of the eye in the manner indicated; and here the marks of design and contrivance are not less obvious than in other parts of the visual organ.

The apparatus by which these effects are produced consists of six muscles, which are placed round the eye-ball at different points. Four of these, simply from their direction, are called the *recti,* or straight muscles, whilst the other two are named the oblique muscles. These latter would have been more correctly called the transverse muscles, since that is the direction in which they are inserted into the eye-ball.



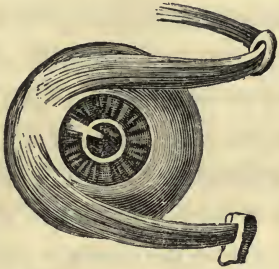
[The muscles of the eye-ball, all proceeding from the extremity of the orbit except the inferior oblique]

The first four, the straight muscles, proceeding from the back part of the orbit, are inserted into the four sides of the globe, just behind the junction of the transparent cornea with the sclerotic coat. The other two, the oblique or transverse muscles, proceed from the front and inner side of the orbit,



[The four straight muscles, removed from the orbit and extended.]

and pass to the eye-ball at right angles from the straight muscles, one passing over its upper surface, and the other upon its under surface, and both being inserted into its outer side, one a little above its horizontal axis, the other a little below it.



[The oblique muscles, superior and inferior.]

One of these transverse muscles,—the superior,—although it proceeds from the fore part of the orbit, actually has its origin at the extremity of the orbit, with the straight muscles; so that it has, as it were, two origins: and the construction and direction of this muscle have always been regarded as among the most forcible proofs of design anywhere to be met with. It is observed to pass above the other muscles, along the upper and inner side of the orbit, until it reaches the front, where, attached to the solid bone, we find a fibro-cartilaginous sheath or pulley, through which it passes, and from whence it is reflected upon the eye-ball at an angle.

This sheath, or pulley, is perfectly smooth, being lubricated by means of a mucous bag, which constantly supplies it with a glairy fluid, and is thus adapted for the free and easy play of the muscle.

The provision of a mucous bag for lubricating it, as clearly points out the means of perfecting this contrivance, as we should be inclined to regard an analogous provision in the case of a machine which had an oil-bag connected with it, and which was so managed that it poured out a due supply of that lubricating fluid upon the wheels or pulleys to which it was attached. If, in addition to the receptacle for the oil, we should observe a means of generating it within the machine, how very perfect then would be our notions of the creative power and genius displayed in the formation of such a piece of mechanism; and such is the very perfect contrivance to which we allude, for not only is this bag a receptacle for the fluid, but it has the property of forming the fluid itself, ready for use as it is required.

All this indicates, in this muscle, an arrangement so perfect, that it is regarded, and very justly, as one of the cardinal points which serve to illustrate and confirm the evidences of design in the animal body.

Surely, then, we may say that those physiologists who have supposed that the oblique muscles are of little or no use must be in a very grievous error, for so much effort, skill, and contrivance would never have been employed to no purpose. To presume that because we do not clearly perceive the uses of certain parts, therefore there is no use in them, is a conclusion to which we should be very tardy in arriving; and we ought rather to persevere in our efforts to ascertain what the offices of such parts really are.

In the muscles of the eye-ball we have perfect examples of the powers which these agents possess in the animal body. They consist of bundles of fibres firmly connected together, those fibres being capable of contracting and relaxing themselves. By this property, when fixed to some firm, bony point, they are capable of changing the position of the parts into which they are inserted, in the same manner as if one were to pull with the fingers at their extremities. So, if we examine the muscles in the orbit, we find them fixed, at one extremity, to a firm point of bone, surrounding the aperture through which the optic nerve passes, and at the other into the outer coat of the eye. Acting from this firm point upon the eye-ball, its direction will be changed according to the situation of each muscle when its fibres are in action. Thus the straight muscle, which is inserted into the outer or temporal side of the globe, by its contraction will turn the eye outwards; that which is inserted upon its inner side, inwards; and so of the other two, upwards and downwards.

The action of the superior oblique, or *trochlearis*, as it is called, from the *trochlea* or pulley through which it passes, is to turn the axis of the eye, that is to say, the pupil, directly inwards. This muscle, although arising from the back part of the orbit, must be regarded as having its fixed point at the pulley, which is placed in front of the orbit, on the inner side next the nose. Now, by exposing the back part of the orbit, and by pulling at the extremity of the trochlearis muscle, it is demonstrable that the eye-ball is turned round somewhat upon its axis, that the insertion of the muscle is brought towards the pulley, and that the front of the eye is turned inwards. This is, undoubtedly, the action of the trochlearis muscle, as I have ascertained by repeated experiments upon the muscles within the orbit. Such opposite opinions are recorded on this point that it is necessary to examine for one's self. Thus ALBINUS, SIR CHARLES BELL, and many others, describe it as turning the eye outwards and downwards, a view which I had myself taken before making the experiment. They presume that the muscle is inserted behind the centre of motion of the eye-ball, and that when it acts it pulls the back of the eye forwards and upwards to the pulley, and so turns the front of the eye in the opposite direction. It is, however, not inserted behind, but directly over the centre of the eye, just under the tendinous extremity of the superior straight muscle, and passing down a little way towards the outer straight muscle. MECKEL, CLOQUET, and others state that it acts in the direction I have mentioned, viz., inwards; and those who will examine for themselves, will find this to be the true action of that muscle.

The action of the inferior oblique muscle rotates the eye-ball in precisely the opposite direction to that of the superior, and likewise turns it inwards; so that if the eye be rotated upwards by the trochlearis, it will be rotated downwards by this muscle, which is therefore the antagonist of the former. Its situation and direction, as well as actual experiment, prove this, for it has its fixed point in front of the orbit, just at the inner angle of the eye, whence it proceeds downwards near the edge of the orbit, passes outside of the inferior straight muscle, and is inserted into the globe just beneath the extremity of the external straight muscle.

The grand error, which has prevented us from arriving at a proper knowledge of the actions of the muscles of the eye-ball, appears to have been in regarding those actions singly; or in classing the muscles into straight and oblique, and presuming that the one class are antagonists to the other, and that those of each class act together in that capacity. Nothing can be more unfounded than such a supposition. No view can be better calculated to keep us in ignorance as to their real uses. It is certainly necessary to possess an accurate knowledge of the actions of the separate muscles before we can properly understand them in a state of combination. And how is this knowledge to be obtained? What muscles act together, and what have a separate or antagonist action? and what are the laws by which these actions are combined, separated, and regulated? These are questions which can only be satisfactorily answered by a reference to the nerves, the agents that regulate the actions of the muscles.

Now, the muscles without the nerves would be utterly powerless: these latter direct, combine, and regulate the actions of the moving powers; and if any injury or disease happen to the nerves, the muscles, to which they are distributed, will be paralyzed. The nerves in the orbit are very numerous, complicated, and difficult to understand. The best way to become acquainted with their functions is to observe to what parts they are sent, and then to ascertain the uses of those parts. Thus we notice that three different nerves pass to the muscles of the eye-ball. The uses of these muscles being to effect the various movements of the eye, therefore the nerves which stimulate these muscles are called *motor* nerves. These three motor nerves of the eye are variously denominated, sometimes in the numerical order in which they come off from the brain, as the third, the fourth, and the sixth. The third is likewise named the *motor oculi*, from its being the principal moving power of the eye, distributed to all the muscles of the eye-ball, except two, and, in addition, to one of the muscles of the eye-lid and to the iris; so that it is justly regarded as the most powerful and important muscular nerve of the eye,—a conclusion, the correctness of which cannot be doubted, when we reflect on the number of muscles to which it is distributed, and the extensive combinations which it directs. The fourth nerve is also called the *trochlearis,* because it goes exclusively to the muscle which passes through the pulley. The sixth is sometimes called the *external motor* nerve, because it goes only to the external straight muscle of the globe.

Considering that the nerves are the directing agents by whose powers the muscles are set in motion, we seem naturally led to the conclusion, that where there are separate nerves there must also be different actions. And when we come to notice the actions of the muscles which are directed by the third nerve, we cannot help observing that, to a considerable extent, there is an agreement between them. These muscles are employed when we direct the eyes straight-forwards, with its modifications inwards, upwards, and downwards; and these form one grand class of movements, in which both eyes always act in concert. They are the joint production of the superior, the internal, and the inferior straight muscles.

In addition to the power of looking straight before us, we have also the ability of directing the eyes laterally, and this cannot be effected by the muscles we have just enumerated. This being an opposite action, requires a different moving power, and a separate nervous supply. Accordingly we find a muscle, the external straight muscle, placed along the outside of the orbit, attached to the outer-side of the globe of the eye, and capable of acting as an antagonist to the muscles supplied by the third nerve, whose action, we have said, is in the opposite direction. For this purpose it is supplied by a separate nerve, the sixth.

An examination of the structure and arrangement of this muscle will show us, that it is much stronger than any of the muscles which are supplied by the third nerve; for, first, it is much longer, owing to the form of the orbit and the position of the eye; secondly, it has a double origin, and therefore two fixed points of action, circumstances which must render it a much stronger and more powerful muscle, and give to it a greater latitude of motion;

and, finally, we may presume, that the nerve being exclusively distributed to this muscle must tend to centralize its influence. The external straight muscle, indeed, may almost be regarded as a double muscle. Having two origins, it is clear that each of these will be capable of turning the eye in a direction somewhat different from the joint action of both. Thus the action of both will be to turn the eye directly outwards, whereas their separate actions will tend to direct it upwards or downwards at the same time.

Thus we have accounted for the actions of all the muscles of the globe, except that of the trochlearis,—that extraordinary muscle, which seems to stand aloof from the others,—not like either of the rest, but, partaking of the common nature of the straight muscles and that of the inferior oblique, compounded of both. Passing with the muscles supplied by the third nerve, and yet having a nerve which is separate and independent, it stands conspicuous and alone, holding the balance, as it were, between the antagonist powers over which it is placed, and apparently capable of acting independently of either.

Now, it is evident, from all these circumstances,

—the extraordinary course it takes, its peculiarity of arrangement, the great power it seems capable of exercising, and its separate nervous supply,—that the trochlearis muscle is intended to act a different and independent part to that of any of the others.

We have seen that there is ample provision for the movements of the eye-ball, in every direction in which we can conceive them to take place. We have seen that the muscles supplied by the third nerve are capable of performing all the movements connected with the straight-forward direction of the eye, whether upwards, downwards, or inwards. We have seen, also, that there is an antagonist muscle placed on the outside of the globe,—that muscle having the power of turning the eye outwards, being the only one which has such a power, and having a special nerve bestowed upon it for this particular purpose. What then can be the use of this additional muscle, the trochlearis? This will be seen as we proceed.

A very remarkable circumstance, next to be considered, is, that the muscles of the third nerve invariably act together in each eye, so as to direct both simultaneously to those objects which are placed straight before us; but when we come to direct the eyes to any object situated to the right or left side of us, we turn one eye,—that nearest the object,—outwards, by means of the external straight muscle; whilst the other eye is turned directly inwards, in order that it also may be directed to the same object. And this inward direction of one eye, when the other is turned outwards, is constant and invariable. Indeed, under no circumstances can we, at the same moment, direct both eyes outwardly. Now, as the muscles of the third nerve are concerned in those actions in which the two eyes correspond, it is manifest that we must have a separate muscle and nerve to direct the one eye inwards with the outward action of the other, because they no longer correspond; so that we have a nerve for the muscles which direct the corresponding motions of the two eyes, which is the third nerve, and we have another nerve for the muscle which turns the eye outwards, where there is no such correspondence in the action of the muscles of the other eye, and that nerve is the sixth. Now, if the external straight muscle were to act in both eyes together, then one eye would be directed towards the object desired to be seen, and the other would be turned away from it; and hence the necessity for another nerve and another muscle to direct the one eye inward with the outward direction of the opposite eye—a necessity met by the trochlearis nerve and muscle.

That this is a matter of great importance cannot reasonably be doubted. The eyes are so intimately connected, and act so completely together, that they cannot properly be compared to organs which are capable of acting independently of each other, such as the hands. The eyes ought, indeed, rather to be regarded as one,—a double organ. So much attention, and so much effort have been displayed in conjoining their actions, that such conjunction is evidently of first-rate importance. The union of the two optic nerves,—a circumstance unparalleled, and which doubtless has reference to this end,—together with the utter impossibility of directing one eye to one object and the other to another, as well as the general correspondence of the two eyes in infants and blind persons,—all lead to this conclusion.

And this affords us a reason why there should be such a complexity of muscles, and such a multiplicity of nerves. How different is the action of the eye-lids from that of the eye-ball! Thus we can, voluntarily, shut or open either eye-lid separately; but, over the eye-ball we have no such control, since it is impossible for us to direct one eye to an object without the other accompanying it. The power is not given to us of causing the muscles to act indifferently, in either eye, with their corresponding or antagonist muscles; and therefore those of the third pair of nerves can never act with their antagonists, those of the sixth pair, the external straight muscles. And in the case of one eye being turned outwards, if the other were to be turned inwards by the internal straight muscle, it must be followed by the action of the same muscle in the other eye, and both would correspond, when such correspondence would be improper. Hence we perceive the necessity for a superadded muscle and nerve—the trochlearis—to act in turning the eye inwards, when the other is directed outwards.*

Now, if the eyes had merely possessed the power of looking straight-forwards, and had not been endowed with that of directing themselves laterally, there would have been no occasion for any muscles, except those which are used in looking straight-forwards; and then there would have been none of that complexity of either muscles or nerves,—one nerve, and one class of muscles, would alone have been necessary. But by supplying us with a muscle to turn the eye outwards, and by farther giving us the power, at the same time, of turning the opposite eye inwards, in order that both may be directed to the same object, a most intricate piece of mechanism has been produced,—two additional muscles and two additional nerves have been added, one muscle and one nerve to effect the outward direction of one eye, and one nerve and one muscle to associate with it the inward direction of the opposite. This view seems to offer a key to the actions of the muscles of the eye-ball; it elucidates the functions of those muscles, and their nerves, in a manner which appears more satisfactory and complete than any other with which I am acquainted. The ingenious observations of my colleague, Mr. Hunt,* opened the way to it;—they furnished the first link of the chain of reasoning. I have pursued the subject, and I do not perceive that any one who regards the action of the trochlearis as being that which I have described it, as turning the eye inwards, can dissent from the explanation above given of the functions of the motor nerves and muscles of the eye-ball. It is one of those points, however, that have puzzled physiologists from the very earliest times; and, therefore, before this is admitted to be the true explanation of the matter, it must be further sifted and examined in all its bearings. In the mean time it is offered as a suggestion worthy of the attention of physiologists, and one which I conceive will bear investigation.

---

* The addition of the inferior oblique seems necessary to antagonize the trochlearis, and is therefore placed under the control of the third nerve.

---

* Vide London Medical Gazette, vol. xix., p. 20.

It is impossible, otherwise than as just explained, to conceive the necessity or use of the trochlearis muscle. Mr. Lawrence has remarked, "the precise use of these oblique muscles is not very obvious, as the recti seem capable of performing every sort of movement which the globe is capable of." And, certainly, if we had been provided with one eye only, or been destitute of the lateral direction of the eyes before noticed, it would be very puzzling to perceive the use of the trochlearis muscle; but to imagine that this muscle should have been formed, and a separate nerve given to it, for the trifling purpose of turning the eye outwards and downwards, when this end could be effected by the muscles previously provided, and with no other intention, appears to be so futile a proposition, that no one, it may be supposed, could seriously maintain it.

The physiology of these muscles has never hitherto been properly understood. And, with respect to the nerves, we can scarcely consider that a rational opinion has been offered, if we except that of Sir C. Bell, who supposes the fourth to be an involuntary nerve, and that the third and sixth nerves are voluntary; but he offers no reason why there should be two voluntary nerves, or why one of them should be distributed to one muscle only, or why the fourth should also be distributed to one muscle only, when he supposes that both oblique muscles are involuntary.

Mr. B. Cooper, in his "Lectures on Anatomy," speaking of the circumstance of the sixth nerve supplying only one muscle, admits that "no clear physiological theory has been formed upon this anatomical fact." To suppose, indeed, that two separate nerves should go exclusively each to a separate muscle, one to turn the eye outwards and the other outwards and downwards, appears absolute nonsense, and could only be entertained in the entire absence of anything like a plausible explanation of the real facts of the case.

Thus, then, with regard to the muscles of the eye-ball, as far as our present views extend, it appears that their actions are regulated by the nerves which are distributed to them; that where a set of muscles is influenced by one single nerve there is there a common or joint series of actions; that when there is a separate nerve going to a muscle which acts in an opposite direction to the others, as the external straight muscle, it is to supply it with an opposite and antagonist power; and, lastly, that when there is a nerve and a muscle superadded to these, as the trochlearis, it has a special and independent action, and in the present instance serves to direct the internal movements of one eye with the opposite motions of the other, so as to direct both, when viewing an object laterally, to the same point.

From the lengthened account we have been compelled to give, in order to a proper understanding of the muscles and nerves of the eye-ball, we perceive what an especial regard has been manifested in perfecting its movements. What a profusion and complication of means, and yet how admirably contrived for the purpose intended! Nor could any suggestions be offered for improving the mechanism by which these effects are produced. That this complicated apparatus should act so beautifully, and with so much regularity, cannot but excite feelings of the utmost wonder and astonishment; and that so many parts should be incessantly in motion, not only without our troubling ourselves about them, but likewise without our suspecting even their existence, when properly considered and referred to that Power which is the source of all good, must at the same time produce emotions of a higher and more enduring character. The best proof that there is nothing superfluous or cumbersome in all this contrivance is the high perfection with which it performs its varied actions.

The manner in which the uniformity in the direction of the two eyes is insured, when looking at objects either straight before or on either side of us, is a matter highly curious and of unbounded interest. But for this special arrangement, this separate and independent action of the muscles of the two eyes when looking sidewise, both eyes would be turned outwards, the one towards the object, the other from it. This would certainly be an imperfection, not only as regards the appearance of the individual, but also as respects the perfection of vision; for the advantage of both eyes being directed to the same point is, that a more perfect image is presented to the mind than when only one eye is used. Thus, at a certain distance, with one eye I can see an object but imperfectly, whilst with both eyes it is quite distinct. Now this, undoubtedly, is of the highest importance, and we cannot do otherwise than regard the beautiful harmony that exists in the accordant movements of the two eyes as another instance proving that not merely our wants and necessities have been provided for, but that our enjoyments and gratifications have formed an object of especial care,—a circumstance which forcibly illustrates the beneficence as well as the power of the Creator.

The necessity for this precise correspondence in the direction of the two eyes is well explained by what is observed when any of the muscles of either eye become paralyzed. Now it happens, occasionally, that the muscles which turn the eye forwards, inwards, and in the other directions in which both eyes act together, become so diseased: when that is the case, the eye-ball is almost motionless, and can only be turned outwards, and objects are seen double. This occasions considerable confusion; and it is curious to observe that as the disease vanishes, and the power over the muscles returns, the two objects gradually approximate, and finally join, and the double vision consequently ceases.

That unpleasant appearance termed *strabismus*, or squinting, arises from an undue action of one set of muscles over that of their antagonists; and we need not be surprised that the eye, in this condition, is almost always turned inwards, when we reflect on the numerous muscles which tend to pull it in that direction.

When the muscles are all in action, balancing each other correctly, we have but one representation of an object perceived by the mind, although there is an image in each eye. The perception of an object singly with the two eyes is a circumstance that has excited much attention. It is, however, the same with the ears, for although there are two, yet is there but one impression of sound; and the brain is a double organ, but the perceptions or ideas created in the mind are single. Vision, as we have said before, is strictly a mental process;

and it is curious that even in squinting persons, although at first they have double vision, yet it very soon wears off, so soon as the mind becomes familiar with the altered circumstances.

Some authors regard the motions of the eye-ball as partaking of the voluntary and involuntary character; and they have proposed to arrange the nerves and muscles according to this view. The most eminent of these is Sir C. Bell. He says, "that these muscles are to be distinguished into two natural classes; and that in sleep, faintness, and insensibility, the eye-ball is given up to the one, and that in watchfulness, and the full exercise of the organ, it is given up to the influence of the other class of muscles."* He further concludes that the straight muscles are voluntary, and that the oblique are involuntary.

From what has been previously advanced, it will be seen that this arrangement is fanciful and unfounded, and that the arguments adduced in its favour are also unsatisfactory and inconclusive. Thus Sir Charles considers the third and sixth nerves as voluntary, and the fourth as involuntary. Now I cannot perceive that any one of these is more or less under the influence of the will than the others. All nerves and muscles are, to a certain extent, involuntary, and all are, more or less, under the influence of the will. Take, for example, the muscles of the eye-lids, as being most conspicuous, and at the same time nearly related to our subject. The eye-lids are closed in sleep without any exertion of the will,—that is an involuntary action; but if we are desirous of closing them at any time, we can accomplish it by the efforts of the will,—that is a voluntary action. So with regard to opening them, and the same with the winking motions, they are alike voluntary and involuntary.

---

* The Nervous System, by Sir C. Bell. 4to. London, p. 179.

The efforts of the will cannot enable us to perform any action with the muscles which is not performed by them involuntarily. For instance, take the external straight muscle, which is as much under the influence of the will, probably, as any other muscle, and Sir C. Bell says its nerve is voluntary; and yet it will be impossible to exert that muscle in one eye whilst the same muscle of the opposite eye is in action. Perhaps this might be done by many and renewed efforts, as in the case of the iris; and we also know that some individuals have acquired a voluntary control over the action of the heart. But these are extraordinary cases. Nor do I perceive that the fourth nerve is less under the influence of the will than the others. I consider it to be quite as easy to direct the movements of the superior oblique as of the external straight muscle, but not more so; and with respect to the inferior oblique, it is supplied with a branch from the third pair, which is universally regarded as a voluntary nerve.

Another error, I conceive, into which Sir C. Bell has fallen, and it results from the foregoing hypothesis of the voluntary and involuntary actions of the muscles, is, in considering that the eye-ball is turned upwards in sleep. I have made many observations on this subject, and have always found, that when individuals are soundly and composedly asleep, the cornea occupies the same position as when they are awake, its lower margin being on a level with the edge of the inferior eye-lid. It is true that in *disturbed* sleep the eye-ball rolls about, and is often turned upwards; but this is not the case in healthy sleep. Nor do I consider that there is any fair analogy between the state of sleep and that of faintness or insensibility. The latter conditions are too much allied to convulsive and diseased action to be compared with the tranquil repose of sleep, when the muscles of the eye-ball are evidently inactive; and, after death, the pupil is certainly not upraised. Indeed the mother or nurse would regard the child as disordered and out of health if she were to observe it with the upper lid raised and the eye-ball turned up in sleep, and would regard such a state as the precursor of convulsions or some other formidable disease. And although some blind beggars, as Sir Charles says they do, may turn up their white balls, (perhaps the more knowing ones,) yet are there very many also to be met with who do not do so.

Sir Charles's observations are always ingenious, and founded on facts that he has somewhere noticed. Thus he has seen, that in persons whose eye-lids have been paralyzed, and who have therefore not been able to close them in sleep, the eye-ball has been turned upwards. Nor need we be surprised that such should be the case, because if the upper lid cannot come down to cover the eye, it is only reasonable to suppose that the ball itself will turn up under the paralyzed lid; but it is not correct to take a case of disease as the index of the natural actions.

On a recent occasion I raised the upper lid of a sleeping infant, and found the pupil occupying the natural central position. I kept the lid raised for a minute or so, when the eye was observed to turn gradually upwards, so as to elevate the front of the eye under the upraised lid and to obscure the pupil. This confirms the observation before made, that when the lid cannot come down, the eye must turn up. So that in the state of sleep,—sound, uninterrupted sleep,—we are to regard the muscles of the eye-ball as being perfectly quiescent, and the eye itself, as we shall afterwards see, protected, at that time, by the sphincter muscle of the lids; and that when the eye is turned up in sleep, it is because the lid cannot come down.

Further observations could not give us any greater insight into the actions and arrangement of these muscles than those we have already had occasion to make, and we may therefore pass on to the next division of our subject.

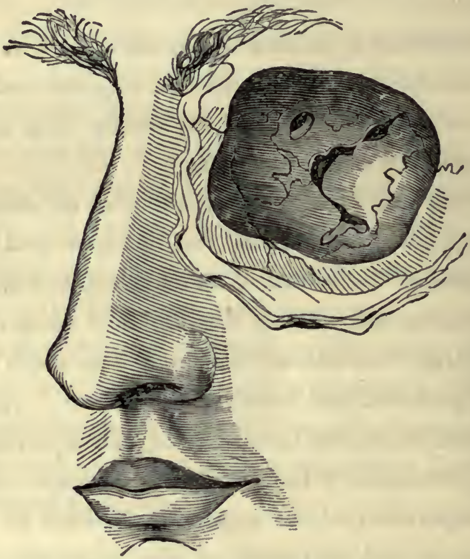
CHAPTER XI.

Of the Defences of the Eye—The Orbit—The Eye-lids—The Lacrymal Apparatus—The Eye-brows.

The farther we proceed in our investigations the more firmly are we convinced that exquisite and inimitable contrivance has been resorted to in every portion of the visual apparatus.

Having now completed our survey of the moving powers, and followed the very intricate and yet most perfect mechanism of the muscles, as well as the puzzling and complex distribution of the nerves, we proceed to consider the manner in which the eye is protected and defended from injury. When we recall to memory the exceeding delicacy of most of the structures of the eye, and the extreme value and importance of the organ in reference to the enjoyment and well-being of the individual, we perceive that it calls for special means of protection: and, in our examination of them, we shall not be disappointed in any expectation we may have formed of their perfection.

First we notice a bony cavity, called the *orbit,* placed between the skull and the face, the brain lying just above and behind it, separated from it by the roof of the orbit, and communicating with it by means of the optic and other nerves through several apertures at the extremity of the cavity.



[The orbit, with the apertures for the transmission of the nerves and vessels to and from the brain.]

The form of the orbit is almost conical, with the apex pointing backwards and the base forwards, the latter being on a level with the forehead and face. Here we observe a direct relation between the shape of this cavity and that of the eye-ball, the one being evidently formed for the other. The eye lodges within the anterior part of the orbit, and as the eye is globular, so the orbit is rounded to receive it. As the cavity proceeds backwards, it gradually tapers off, where it is still adapted for the gradual swelling out of the muscles and for the passage of the nerves and blood-vessels. The space between the muscles, and between these and the eye-ball, and the other contents of the orbit, is accurately filled up and occupied by an adipose, fatty matter, which forms a soft and unresisting medium, exists in great quantity, and must tend materially to facilitate the movements of the globe.

Now, this cavity is not scooped out of the skull, as one might make a hole in a block of wood, but has a strict relation to all the bones of the face and of the skull. The latter are, in fact, arranged with relation to one another, and to the contents of the orbit, so as to leave this space for the reception of the eye and its appendages. They are indented or dove-tailed into one another in the most precise and orderly manner. No less than seven different bones are concerned in the formation of this cavity, and each of these is formed with strict relation to it.

In noticing the front of the orbit, we perceive that the outer side is placed much more backward than that nearest the nose, so that the eye is not so well defended on that side; but, as a compensation, this inferiority of defence is made up for by the increased field of view in the lateral direction, which this obliquity of the outlet allows.

Now, if we were to tax our ingenuity to the utmost, could we possibly suggest any situation, or any arrangement, superior to the one we are now considering? It is scarcely necessary to point out the prominent position the eye enjoys from its being placed in this cavity. No other situation could be so admirably suited to the objects contemplated in the formation of this invaluable organ. As a watch-tower, it is so placed that it may command a most extensive, almost unlimited range of vision; and, by its immediate proximity to the brain, the centre of all sensation and perception, its impressions are conveyed to that organ with a degree of perfection and rapidity beyond what we can conceive.

Some persons have employed themselves in somewhat idle speculations as to whether or not a better situation than the orbit could not have been found, and have contended that the hand would have been an excellent quarter to have had the eye located in. In the lowest grade of animals, indeed, the eye is often found in connexion with the tentacula; but we cannot for a moment admit that such a position would have been suitable for man and the higher animals. It would have exposed this tender organ to numberless chances of mutilation from which it is now happily free, and we have no need to wish for any such change.

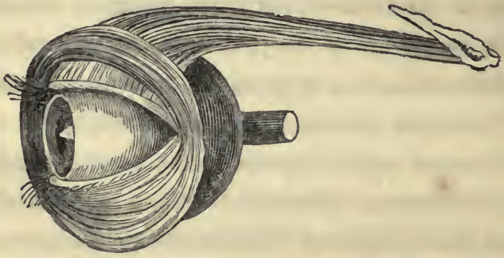
In addition to this bony cavity, in which the eyeball is so securely lodged, there are other parts which contribute to its safety and protection. It is obvious that it would not have answered the purposes for which it is designed, if the front of the eye had been covered over or surrounded with bone, as it is on each side and behind it. It might be thought that the eye would have been much more secure if it had been thus protected in front, and had possessed only a small aperture just to peep through. But this condition would have been quite inconsistent with the extensive motions of which the eye is capable, and it would have been almost useless had such been the case.

Instead of this, the eyes are provided with an apparatus, a kind of moveable curtain, which is placed in front of them, and is either raised or lowered, according to the pleasure or condition of the individual. This provision is the *eye-lids.* As we have likened the front of the eye to a window, we might name these the window-shutters of the eye, for by them we exclude the light from obtaining access to it when its presence would be disagreeable, as in a state of sleep.

Although there are two lids to each eye, it is the upper that is principally concerned in closing over, as well as in uncovering it, whilst the lower is very nearly passive. The lower lid, however, forms an important part of the apparatus, for it covers over the lower front of the eye-ball, with which it is in close contact; and it serves in a high degree to lubricate and moisten its surface, and prevents the lacrymal fluid from running rapidly from the surface of the eye, which it would otherwise do. It is so constructed that when the upper lid descends, the margins of the two lids are accurately fitted to one another; though they are so contrived that a little canal or gutter is formed between them, by which the lacrymal secretion, or tears, passes along to the ducts in the inner corner of the lids. Thus, in a state of sleep, that process is enabled, by this contrivance, to go on uninterruptedly.

The upper eye-lid, we have said, is by far the most active, and it is also much more extended than the lower. When it is drawn up, the skin forms itself in folds or wrinkles; but when lowered, it is quite smooth, from its extension. Both lids, when drawn together, cover over the space in front of the orbit, and thus completely hide the globe. The lower, having scarcely any motion, is not liable to be changed in position or shape; whereas the upper, enjoying very extensive motion, has both materially altered when raised or depressed. The latter, when lowered, has its margin nearly straight, corresponding to that of the lower lid; but when elevated, it forms an arc or segment of a circle.

This extensive motion of the upper lid is accounted for by its having muscular fibres within its structure, arranged in opposite directions, and having antagonist powers. Concentric fibres run around the eye-lids, having an orbicular shape, and forming a sphincter muscle,—the orbicularis,—which draws the lids in contact.



[Muscles of the eye-lids, the elevator passing back into the orbit, the sphincter surrounding the front of the eye. See also the engraving of these muscles, page 164.]

Another set of fibres, which take their course from above downwards, are inserted into the margin of the upper lid, and are unconnected with the lower. These form the elevator muscle of the upper lid (*levator palpebræ*), and, when in action, pull it upwards, so as completely to uncover the front of the globe. Being inserted into the central portion of the lid, and pulling upon its point of insertion, it necessarily acts chiefly upon that point; and as it has very little influence over the lateral portions of the lid, it draws it to the upper margin of the cornea, in the form of a semi-circle or arch, as before noticed; by which means nearly the whole of the cornea and of the iris is exposed to view.

The comparatively motionless state of the lower lid is doubtless owing to its having no antagonist fibres, as the upper lid has; but Sir C. Bell has shown that the action of the levator of the upper lid has a tendency, by pushing the eye-ball somewhat forwards, to depress the lower, at the same time that it raises the upper lid. When we close the lids forcibly, it is easy to see that the lower lid is considerably elevated, but in the instinctive action of covering the eye, as in sleep, this is not the case.

How nicely is the proper relation established between the margin of the lower lid and that of the cornea: we notice the margins of each precisely corresponding. Had the margin of this lid been brought up to the centre of the cornea, opposite the pupil, we see how it would have interfered with vision; and it would have been necessary to have had a depressor muscle of the lower lid to have removed it from the axis of the eye.

The winking motions of the lids are highly curious and important. As has been remarked, they form an instance of the fact that the most common actions are very often the least observed, and are at the same time the most interesting. By the almost incessant rising and falling of the upper lid this winking motion is produced, and it is highly useful, inasmuch as it tends to diffuse the tears equably over the surface of the cornea, so as to keep it moist, and to wipe off any foreign matter that may obtrude upon it. Sir C. Bell has remarked, that "while the upper eye-lid falls, the lower eye-lid is moved towards the nose, and forms a part of that curious provision for collecting offensive particles towards the inner corner of the eye. If the edges of the eye-lids be marked with black spots, it will be seen that when the eye-lids are opened and closed, the spot on the upper eye-lid will descend and rise perpendicularly, while the spot on the lower eye-lid will play horizontally like a shuttle."*

Every one must have felt the correctness of this observation, for in whatever portion of the eye the irritation be felt, there is this continual play of the lids maintained until the particle of dirt has been propelled to the inner corner of the eye, when relief is at once obtained. It is by this action that, after being much in the dust, we find it collected in such quantity in the inner corner of the eye; and on first awaking we always find an accumulation at this point. Here there is a depression, or basin, which serves to receive the superfluous tears, as well as these little particles of dirt, which thus get discharged from the surface of the eye.

---

* The Nervous System, p. 182.

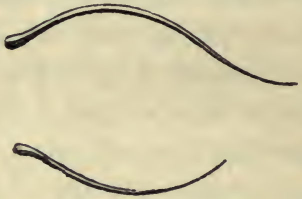
These winking motions, then, are produced by the continual play of the two antagonist muscles, the sphincter and the elevator. Each is alternately in a state of action and of relaxation, the elevator having the most power when we are awake, but being totally inactive during sleep, or when the lids are voluntarily closed.

In noticing the action of the elevator muscle of the eye-lid, it is curious to observe the perfect correspondence existing between it and the elevator of the eye-ball—the superior straight muscle. If we turn the eye upwards, the superior eye-lid is raised at the same instant. And this is another instance of the harmony and relation of one part with another with which it acts, and which is everywhere so striking. If the eye-lid did not turn upwards at the same instant, the eye-ball would be turned under the lid, and nothing would be seen. This is not effected by the eye-ball pushing up the lid, but arises from a union of the fibres of the two muscles at their origin at the back part of the orbit. They have one common origin, and the two muscles might properly be regarded as branches from one common stock. The effect of this arrangement is, that when the elevator of the eye-ball contracts itself, it also pulls upon and excites contraction in that of the lid. Moreover, both receive branches from the same nerve,—that nerve which we have before spoken of as controlling so many of the muscles of the eye, and as being distributed also to the iris, by which means the direction of the pupil, that of the eye-ball, and of the upper lid, are made to correspond, where a want of such correspondence would be a very serious defect. An affection of this nerve, we find, will disarrange all this agreement and produce paralysis of all these parts.

In the different textures of which the eye-lids are formed, the same relation between the means employed and the end to be attained, is observed equally as elsewhere. We have said, that with regard to size they are perfectly and correctly proportioned to the organ which they are destined to cover and protect. A similar remark may be made with regard to their consistence. Some might be tempted to think that a mere flap of skin, or other loose substance, would have answered to cover over the eye. Not so, however: to be useful, the covering must have some degree of firmness, and to secure this a thin plate of cartilage is introduced under the skin and muscles of the lids. To this cartilage the name of *tarsus* is given. It is on a similar principle that we introduce a piece of pasteboard into a shade for the eye, instead of using merely a bit of thin silk, which has little consistence, and would, therefore, by itself, be of but little utility. This cartilage is firmer at the margins of the lids, where they join each other, so that it is well adapted to support the eye-lashes, which are planted between it and the skin, and it gradually becomes thinner as it recedes from this point.

The eye-lashes themselves, the *cilia,* are arranged with the utmost order, and as a means of defence to the eye are worthy of considerate attention. They have bulbous roots, and grow from the margins of the lids. In like manner as a vegetable sucks up nourishment from the fluids and other principles of the earth in which it is embedded, so these absorb the nutrient fluids of the body, and consequently possess a living principle.

They are as much secreted from the blood as any other structures of the body. They, like the nails of the fingers and toes, originate in a very fine vascular pulp, which continually adds new matter to the root. When plucked from the lid the hole through which they push themselves is distinctly visible, and if the margins of the lids become ulcerated they fall out, which occasions considerable disfigurement and inconvenience to the sufferer.



The eye-lashes.

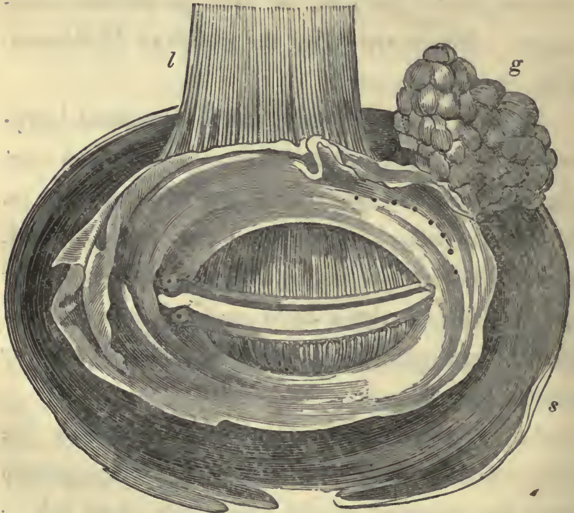
The cilia are longer and much more numerous in the upper than in the lower lid, fewer in the corners of the lids, and more thickly studded in the centres. In form they present a beautiful curve, those in the upper lid being curled upwards, those in the lower lid downwards, so that the convex surfaces of each are opposed to and intertwine with each other when the lids are closed: when brought together they form a barrier to the entrance of very light particles of matter, which might otherwise intrude. Every one knows the excessive irritation that is produced from a bit of dust getting upon the surface of the eye, and if it were not for this defence, such a source of annoyance we should be doomed almost perpetually to endure.

To lubricate the edges of the lids a considerable number of little glandular bodies are distributed throughout their structure; little furrows are provided in the tarsal cartilage in which they are lodged, and they terminate in open mouths upon the margins of the lids, and emit an unctuous substance. These are called the glands of *Meibomius,* from their discoverer.

Another glandular body, called *caruncula lacrymalis,* is situated in the inner angle of each eye, just between the lids, and is very distinct from its forming a conical eminence; it secretes a fluid, which aids in moistening the eye, and we may observe two or three little apertures for its discharge, springing from each of which is a very minute hair.

As a means of connecting the eye-lids with the globe of the eye, a fine, delicate membrane passes from the margins of the lids, lines their whole internal structure, and becomes reflected, forming numerous folds at the point of reflection upon the eye-ball, and passes entirely over its anterior and transparent surface. From the circumstance of its connecting the eye with the lids it is called the *conjunctiva.* It is believed to be a secreting surface, pouring out a mucous fluid. These means of moistening the eye are very numerous, and we see what care and attention has been bestowed upon this one special point.

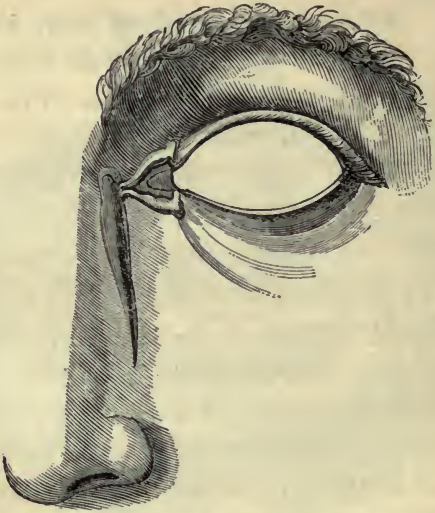
But we have still to mention the most important portion of the hydraulic apparatus of the eye,—



[Posterior view of the eye-lid: *l,* the levator muscle; *s,* the sphincter; *g,* the lacrymal gland. A number of little apertures are seen opening on the inner surface of the lid, beneath the gland; two others are seen in the opposite corner for the removal of the tears. The Meibomian glands are lodged in the perpendicular furrows under the conjunctiva.]

the *lacrymal gland,* with its accessory tubes and ducts. In the outer corner of the orbit, and in its roof, a little depression in the frontal bone is noticed for the reception of this gland. It is about the size of a small almond, flattened, and of a somewhat oval shape. Its office is the secretion of the tears,—that peculiar fluid with which every one is familiar. To convey it from the gland to the surface of the eye six or seven ducts are provided, which open upon the inner surface of the superior eye-lid. We have before noticed how, by the winking motions of the lids, this fluid is equably diffused and carried over the surface of the eye-ball, and that it is thus conveyed to the inner corner of the lids, where a little basin (*lacus lacrymalis*) is ready to receive it when accumulated, previously to its being carried off by other ducts next to be mentioned.

If we look carefully at the inner corner of the eye-lids, just at their termination near the nose, we shall discern in the margins two very minute apertures, one in the upper the other in the lower lid; these are called the lacrymal *puncta.* They are the orifices of two capillary tubes which suck up the lacrymal fluid when it is collected, and which runs over the little reservoir or basin of which we have before spoken. These tubes are therefore called the lacrymal canals; they proceed one from each lid, inclining towards each other, so as to leave a triangular space, which is occupied by the little gland, the caruncule before noticed. They soon terminate in a small receptacle, called the lacrymal sac: as they approach this sac they gradually approximate and unite in one common duct, just where they empty their contents into it. The *lacrymal sac,* then, lies close in the corner of the eye,



[The lacrymal passages from the eye into the nostril.]

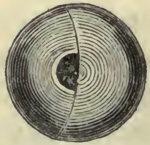
and between it and the nose, and is lodged in a depression of the bone purposely provided for it. It is a membranous bag of a somewhat oval shape, and communicating with a bony canal called the *nasal duct,* through which the tears are discharged into the nostrils.

In birds and quadrupeds an additional means of lubricating and of defending the eye is likewise found. As well as the lacrymal, birds have another glandular body, the *Harderian* gland, (see fig., p. 68,) of very large size, for pouring out a much thicker and more adhesive fluid, placed on the side of the orbit near the nose. It is in immediate connexion with the membrane called in quadrupeds the *haw,* which is a contrivance for sweeping and covering over the cornea, but which does not exist in man or in the quadrumana. These latter, having the power of using their fingers, have no occasion for such a contrivance, which is evidently a compensation for the want of these instruments in quadrupeds and birds. We have no evidence of quadrupeds ever suffering from the irritation of dust getting into their eyes, and it is by these means that it is prevented or removed.

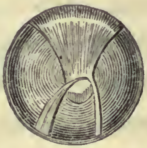
In fishes, too, there is no provision of this sort;

they have no eye-lids, nor glands for the secretion of the fluid necessary in land animals, because they are surrounded by water, which continually washes the surface of the eye and prevents anything adhering to it.

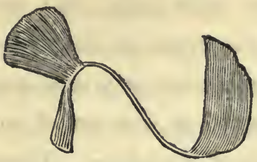
In birds, the nictitating membrane, or *third eye-lid* as it is called, is moved by a more complex apparatus than the haw of quadrupeds. This membrane is cartilaginous and elastic. When it is drawn out, which it is by the action of its muscles, it returns to its place in the inner corner of the eye by its own elasticity, as soon as the action of the muscles ceases. These muscles are attached to the back of the eye, near the optic nerve. One is called *quadratus,* the other *pyramidalis,* from their



[The nictitating membrane of the bird drawn over the front of the eye.]



[Back of the eye, showing the muscles of the third eye-lid.]



[The nictitating membrane with its muscles removed from the eye.]

shape. The latter has a long, tendinous cord, which passes through a kind of canal or pulley in the former to the membrane, to which it is firmly fixed; and when both these are in action, the membrane is drawn out over the surface of the eye, of which it can cover about one half.

In quadrupeds the haw is pushed out of its recess in the inner corner of the eye, and is drawn over it, by the pressure of certain muscles of the eye-ball, and returns by its own elasticity.

Probably the chief agent in protruding this membrane is the *retractor* muscle, which is peculiar to the eye of quadrupeds. It arises from the bottom of the orbit, comes forward, encircling the optic nerve, sometimes in four fasciculi, sometimes in two, and is inserted into the sclerotic coat just behind the insertions of the straight muscles. In some experiments on the eyes of quadrupeds, I have observed that by pushing the globe backwards and from the outer side, this membrane was brought over the front of the eye. It is known also that the retractor muscle is supplied by the same nerve which is distributed to the external straight muscle of the globe. These facts would seem to imply that there is a connexion between these two muscles, and that both are brought into play in the protrusion of the haw. Sir C. Bell has conjectured "that there is something common to the retractor oculi and the rectus externus."* In the quadrumana and in man, not only is there an absence of the haw, but also of the retractor muscle.

Now it is scarcely possible for any one to regard these otherwise than as additional facts, tending to prove, in the most striking and convincing manner, the workings of a supremely intelligent and beneficent Creator. In all these arrangements so perfect are the contrivances exhibited, such adaptations of means to a given end so unequivocally shown, that no further argument or illustration can be required in confirmation. The proofs of design are ample, self-evident, and complete.

Before quitting this part of the subject, however, we may briefly notice the last of the accessory parts of the eye,—the *eye-brows.* They are particularly important as organs of expression, in which the eyes themselves so largely participate.

---

* Nervous System, 4to, page 215.

The eye-brow forms the upper boundary of the orbit; it is covered over with the common integument of the body,—the skin, and is ornamented with a row of hairs, which corresponds with the arched form of the eye-brow itself. Those hairs which are planted nearest the nose are very short and nearly erect; whilst those which proceed towards the temple and from the middle of the brow are curved and much longer. In this respect they correspond with the arrangement of the muscular fibres which are placed beneath them, and to which the motions of the eye-brow are owing.

These hairs are much more numerous and bushy in some individuals than in others, and that generally in dark-haired persons. This contrivance has been likened to a pent-house, by which the perspiration is prevented from running down upon the eyes. It certainly forms an ornamental appendage to the eye and forehead, in which point of view it should chiefly be regarded; for beauty, as well as strict utility, is evidently a part of the general design of creation. And the eye-brows are eminently useful or otherwise in giving a pleasing and interesting appearance to the individual, according as the muscles are arranged in giving expression to them. According then as these instruments are used we have it in our power to be agreeable and good-looking, or the reverse; and an interesting expression of the countenance is well known to be very often more captivating than the mere possession of a beautiful form of face. These effects are accomplished by the aid of certain muscles, which most fortunately are not altogether involuntary, but are more or less under the influence of the will; and if they are much used, as they are in frowning and other disagreeable actions, the individual will be sure to acquire a haughty, supercilious, and forbidding appearance; whilst, on the other hand, if these muscles are but little used, the countenance remains tranquil, the eye-brows and forehead unfurrowed, and the whole expression benign and pleasing,—a point which all ought to aim at who regard the human face as an emblem of divinity.

CHAPTER XII.

On the Sensibility of the Eye.

THE sensibility of the eye is proverbial. Every one has experienced the misery which a particle of dust, so small as to be almost invisible, produces when it is lodged fairly between the eye-ball and the lids. Every one knows, also, that very uneasy sensations are the consequence of a too powerful degree of the stimulus of light, such as on first waking out of sleep, particularly in the night season, or on looking at the sun or any other highly illuminated body.

Sir C. Bell has correctly remarked, that the exquisite sensibility of the general surface of the body is the best and most effective safeguard or means of its defence. That this high degree of sensibility, with which the visual organ is endowed, has been bestowed for the same end cannot be questioned.

Now, it has been the custom to consider this sensibility to light as seated exclusively in the retina, the nervous membrane in the interior of the eye. Such a view seems to be much too limited. Indeed, very confused ideas appear to be entertained with regard to the sensibility of the retina. Majendie says that in introducing a needle into the eye, no pain is felt when the retina is touched or pricked. "A false idea," he further observes, "is generally entertained of the sensibility of the retina; it is represented as the prototype of sensible organs: it is affected even by the very light, it is said." Certainly, the sensibility of the retina ought to be regarded in relation to the images of objects, and not with respect to the agent by which those images are produced.

Sir C. Bell makes the following remark on this part of our subject:—"The point of the needle, in passing through the outer coat of the eye, gives a sensation of pricking, which is an exercise of the nerve of touch; but when the point passes through the retina, which is the expanded nerve of vision, and forms the internal coat of the eye, the sensation that is produced is as of a spark of fire. The nerve of vision is as insensible to touch as the nerve of touch is to light." Upon this we may observe, that if the nerve of vision be insensible to touch, of which there can be no doubt, then touching it with a needle could not produce light, any more than by concentrating light upon the hand should we produce touch.

Dr. Paley has assumed that the pupil closes *entirely* in the eyes of cats, owls, and other creatures which prey by night. "The final cause of which," he says, "seems to be this:—it was necessary for such animals to be able to descry objects with very small degrees of light. This capacity depended upon the superior sensibility of the retina, that is, upon its being affected by the most feeble impulses. But that tenderness of structure which rendered the membrane thus exquisitely sensible, rendered it also liable to be offended by the access of stronger degrees of light."

Now, the means of enabling these creatures to descry objects with very small degrees of light has been provided for by a beautifully shining and reflecting surface placed behind the retina,—the *tapetum,* of which we have before treated. Such a contrivance would have been unnecessary if the retina possess this exquisite sensibility, which, however, is entirely an assumption unsupported by facts. The retina, in them, possesses no greater tenderness of structure than in other beings. Nor is the dark pigment given for the purpose of defending the retina, on account of its sensibility, otherwise it should have been placed before the retina and not behind it; but it is intended to prevent reflection of light within the posterior chamber.

Dr. Elliotson, in a clinical lecture reported in the Medical Gazette,* mentions a case of intolerance of light, which he considered to arise from an affection of the retina, and which was relieved by the local application of belladonna, a substance which has the curious property of dilating the pupil. Now, if it had been an affection of the retina, the dilated state of the pupil must have increased the malady, at least if the sensibility to light reside in that membrane. But Dr. Elliotson considers that belladonna deadens the sensibility of the optic nerve, or, in other words, paralyzes the retina. Now we know that it paralyzes or deadens the sensibility of the iris, because the pupil becomes dilated and motionless; but where is the evidence of its paralyzing the retina? In the case in question the patient could see better after its application. So that, according to Dr. Elliotson's view, belladonna deadens the sensibility of the iris and suspends its functions; but, in deadening the sensibility of the optic nerve, its functions are rendered more perfect! Doubtless the patient was relieved by the influence of the belladonna in allaying the morbid sensibility of the surfaces of the eye.

---

* Vol. viii. p. 381.

In the following observations, it will be very evident that sensibility to light is not peculiar to the retina; that it is not peculiar even to the eye, nor indeed to the animal economy. It is well known that many plants, if excluded from light, are perfectly colourless, and that some, otherwise acrid and poisonous substances, if nurtured in that condition are quite harmless. It is further familiar to us, that plants grown in dark places invariably direct themselves towards the light. Many plants, likewise, close their leaves and flowers during the dark and expand them with the opening day. As if to make the analogy more complete between the animal and vegetable kingdoms, there are also plants which expose their leaves only during the night and shut themselves upon the approach of day, in like manner as many animals shun the light of day and appear only in the dark. LINNÆUS made experiments which prove that it is the absence of light, and not of any other agent, as had been supposed, that causes the relaxation or sleep of plants. Nothing, indeed, throughout nature, is more striking than the regularity with which some flowers follow the course of the sun and shut themselves up when he disappears. With these facts before us, we are entitled to consider that there is some analogy between the effects of light, as observed in certain flowers, their regular contraction and expansion, not to mention their frequent resemblance in form, and in variety and beauty of colour, and the corresponding phenomena noticed in the organs of vision.

Certain of the lower animals are not possessed of an organ of vision, and yet unequivocally evince a sensibility to light. On this point Dr. Grant observes,—" The most numerous, the most varied, and the most important impressions, are those which animals receive from light, so extensively spread through nature; indeed this agent exerts an important influence on the three kingdoms of natural bodies, on the constitution and properties of minerals, and on all the vital movements of plants and animals. Many animals, like plants, are obviously affected by light without possessing organs of vision, or even a perceptible filament of nervous matter; and where the nervous system and the organs of the senses are the most developed, these great centres of the animal functions are situate where they may best watch over the vegetative. As plants, guided by light, open and close their flowers and their leaves, or follow, with their expanded flowers, the course of the sun, or seek the light with their branches and their leaves, without a nervous system, so we perceive the gemmules of poriferous animals guided in the selection of their place for fixing and developing by the influence of the same agent. Some zoophytes expand or contract their body or their polypi according to the intensity of the light; and the free moving hydræ seek the most lighted situations in their aquatic element without exhibiting either organs of vision or nerves, and the topographical distribution of the spontaneously moving gemmules in that class of animals on the surface of rocks, or caves, or precipices, or the bottom of the ocean, appears to be regulated chiefly by the influence of light. The spontaneous motions of medusæ, and other gregarious acalepha, appear also to be guided by this agent, without their having distinct organs appropriated to it."*

We further ascertain, as we ascend the scale of animated beings, that organs of vision, very minute and appreciable only by microscopic aid, are by that means distinctly seen, bearing evidence of an acute sensibility to light, and yet possessing not the slightest appearance of nervous filaments. This is the case not only in the simple polygastric animalcules, but also in some of the annelida; and these eyes are of so rudimentary a character, that it is probable they possess merely a sensibility to light, and have no perception of objects. Moreover, the best authorities state that certain mammalia and reptiles, such as the mole, shrew, mus capensis, proteus, and others, have the eye in the same rudimentary and imperfect condition, and are not in possession of an optic nerve, and consequently have not perfect vision; but these animals, nevertheless, are sufficiently sensible to light; and the only nerve which penetrates the eye is a filament from the common nerve of sensation to the head and face, the fifth.

A curious effect of the absence of light on some animals is that of retarding the process of their transformation. Dr. Edwards made some experiments on tadpoles. A certain number were placed in precisely similar circumstances, except that one half of them were excluded from light: almost all those who were thus deprived of that agent did not become changed into frogs, notwithstanding that they continued to grow, whilst the others underwent the usual transforming process.

---

* Lectures in the Lancet, vol. ii. p. 577 (1833-4).

The same eminent observer notices that "the brown tinge observable upon persons who are much exposed to the sun, as it scarcely occurs except on exposed parts, and does not require a great intensity of heat, is justly attributed to the peculiar action of light." He considers, likewise, that the exposure of the whole surface of the body to the light is very favourable to its regular conformation; and farther, that a want of sufficient light has a tendency to produce those deformities seen in children affected with scrofula. In confirmation of this view the authority of HUMBOLDT may be quoted, who affirms that he has not seen a single instance of natural deformity amongst many thousands of American Indians; and that it is especially rare among those who have the skin strongly coloured. Dr. Edwards concludes his observations on the physical effects of light as follows:—"It is true that the light which falls upon our clothes acts only by the heat which it occasions, but the exposed parts receive the peculiar influence of the light. Among these parts we must certainly regard the eyes as not merely designed to enable us to perceive colour, form, and size; their exquisite sensibility to light must render them peculiarly adapted to transmit the influence of this agent throughout the system, and we know that the impression of even a moderate light upon these organs produces, in several acute diseases, a general exacerbation of symptoms."*

The inference we are entitled to draw from all these facts and reasonings is unquestionably that it is but a very limited and very partial view that is taken of the agency of light when it is said, as it usually is, that the retina is the immediate and sole seat of sensibility to light, and that the closure of the pupil and of the eye-lids is intended merely to guard and defend that portion of the organ.

The effect of light upon the iris and eye-lids varies according to its intensity; a moderate degree of its stimulus seems to cause expansion, whilst an excess, as well as an absence, produces the opposite state. It is a well-known fact that we find it more difficult to arouse ourselves from sleep in dark winter mornings, and the reverse; and many individuals cannot sleep at all when light is present. In very dull days, too, it is not uncommon for us to become stupid and heavy, and it is indeed generally ascribed to the condition of the atmosphere; in this state we have recourse to unusual exertion to arouse ourselves from this listless inactive condition; or, on the other hand, a comfortable nap restores to us our wonted energy.

---

* Dr. Edwards on Physical Agents, translated by Dr. Hodgkin.

In stating this opinion in a former work, I have been regarded as somewhat fanciful; and yet I think few sentiments better accord with our everyday experience and sensations. The following quotation from Dr. Kidd's Bridgewater Treatise will show that I am at least not singular in this view:—"Although it would be difficult to prove directly that there is any necessary connexion between darkness and sleep, yet this connexion is rendered at least highly probable by the effect usually produced on the approach of darkness upon animals in general, but more remarkably on birds; for, with the exception of those whose habits are nocturnal, all birds betake themselves to sleep as soon as night approaches: and if darkness should anticipate night by many hours, as happens when any considerable eclipse of the sun takes place in the middle of the day, we still find that the birds of the field as well as our domesticated fowls give the same indications of composing themselves to sleep as at the regular period of sunset. If it should be said that this does not more serve to prove a connexion between darkness and sleep with reference to these animals, than to prove the effect of a long-continued association resulting from their habit of going to roost at sun-set, it may be asked, why should darkness, unless from some inherent cause, lead them to compose themselves to sleep at the hour of noon instead of the usual hour of evening,—since, on the one hand, periodical states of the animal system do not usually recur before the termination of the habitual period,—and, on the other hand, the individuals cannot, at so early an hour, have experienced such a degree of exhaustion as would of itself invite to sleep?"

As well as their composing themselves to sleep on the approach of darkness, the constant habi of these creatures of waking with the earliest morn is in favour of this view. If the presence of light be disagreeable to nocturnal animals, obliging them to sleep in the day, we may certainly with reason infer the opposite in those of contrary habits. The physical conformation of each is favourable to these habits. In the one class the presence of light is irksome, and they avoid it; in the other, darkness is the evil, they are not suited to it, and exert themselves only in the light of day. In the short days of winter animals have not half the exertion of summer, particularly birds, but notwithstanding they retire to roost at sunset, not from fatigue it may be presumed so much as on account of the absence of light. In a state of nature there can be no doubt that this is the general law: civilization however changes not only the moral but the physical condition of man. And, although fashion has reversed the order of nature, yet the husbandman still rises with the sun, and retires to sleep with the disappearance of the luminary of day.

Without positively denying that the retina may possess some modified sensibility to light, I advocate the doctrine that the eye generally possesses that sensibility, and that it is in the outer surface of the eye that the peculiar irritability is situated when we have a painful feeling from an excess of light. I presume farther that sensibility to light is a function, not of the optic, but of the fifth nerve. The case of an individual who was some time since under my care confirms this view. He had evidently a paralytic affection of the fifth nerve of one side, for he had lost all feeling on the affected side of the face; he possessed no power over the muscles of that side, and therefore could not close the eyelids, and his mouth was twisted to the opposite side, and his taste was very much impaired. The sight of both eyes was quite good, showing that the optic nerves were quite free from disease. The effect of a very vivid light was strikingly and markedly different in the two eyes, for the healthy eye could not bear the same amount of light for a single instant which produced no impression on the eye of the paralytic side; the flame was distinctly visible to the eye, but it produced no irritation. This I believe to be quite a novel view, and the experiment happily illustrates the correctness of the theory.

Many instances have come under my notice of persons perfectly blind in whom this sensibility to light nevertheless remained. I will mention but one. This individual, from frequent attacks of inflammation, had lost one eye. He was not merely blind, but the eye-ball had partially wasted, or become absorbed, so that there was very little of it left. He spontaneously remarked to me on one occasion, at a period of several years after he had lost the sight, the singularity of the circumstance that a strong light was very offensive to this lost eye, when in a somewhat inflamed condition; so much so, that he was obliged to cover it up from the ordinary daylight, as if his vision had been ever so good. So also, in the case of children who have lost both eyes, their mothers or nurses have stated that they become uneasy and restless when in the dark, and that they usually awake with the commencement of daylight and become sleepy at the close of day.

The result of experiments on the fifth nerve supports this view. The celebrated French physiologist MAJENDIE made many experiments on the nerves of the eye. In one of these he divided the fifth nerve, and on applying a lighted taper to the eye the animal appeared quite unconscious of it; he increased the stimulus by means of reflectors, with the same result. At length he converged the sun's rays upon the eye by means of a lens, when the animal appeared to be slightly conscious of sensation. From this experiment Majendie erroneously concluded that the vision of the animal had been destroyed, when it was clearly nothing but the sensibility to light that had been impaired.

We cannot better illustrate the distinction between the sensibility of the eye generally and the special sensibility of the retina, than by referring to our sensations when looking directly at the sun. A painful feeling is excited in the exterior of the eye, which induces us instantly to withdraw our gaze, whilst the impression on the retina is perceived by a luminous appearance,—the image of the sun,—which remains long after the external impression is gone.

In the *Albino*, whose aversion to the light of day is usually considered to be owing to the irritable condition of the retina, from its not being defended by the pigment, I regard it to arise from the confusion of vision which results from the optical deficiency, the pigment being one of the essential parts of the apparatus, and equally necessary in an inanimate telescope as in the living eye. On one occasion I asked a person of this description if the light was very painful to her in the day time: it was a bright, sunny day. She replied, "no; it does not hurt me, but I cannot see so well."

Every one is familiar with the excessive irritation which light produces when the eye is inflamed from even a particle of dust getting upon it. Of course it is the sensitive surface of the eye that is affected, there being no derangement of the optic nerve in such a case; for if the light be diminished, the sight is unaffected. And, on the other hand, in many of the worst cases of affection of the retina, there is no morbid sensibility to light.

Many other phenomena show that this sensibility to light is on the surface, and is connected with the nerve of sensation, for the irritating effects are frequently extended to the neighbouring parts, as the eye-brows and the nostrils. Thus exposure to a bright light frequently produces pain in the head and sneezing. It is very common, when examining children affected with ophthalmia, that when the eye is exposed, they immediately commence sneezing. One boy, whose eyes required some stimulating application, invariably had a fit of sneezing after it. Some time since, as I was passing round the prison of this town, a man, who had been confined in a dark cell, was released, and it was curious to observe that, on the moment when he emerged from darkness, he commenced winking and sneezing at a tremendous rate, which continued until he had become familiarized with the change of situation.

Another illustration will suffice to substantiate the position. We will refer, in the last place, to the practice of those individuals who, from their occupations, have their eyes continually exposed to a strong glare of light, and to that of the inhabitants of high northern latitudes, such as the Tartars, who find great inconvenience from the powerful reflection of light from the snow, and who suffer much from what is termed snow-blindness. These persons are in the habit of defending the external parts of the eye by means of a frame with a central aperture, through which the light passes to the retina. Now, here we have every part of the eye defended from the light except the retina. It must be evident, on the slightest reflection, that the object of such individuals is to defend the sensitive, exterior portion of the organ, whilst almost as much light as ever must pass through the pupil to the retina. Indeed, if it be the retina that requires to be defended, the closure of the pupil must be the only effectual relief in such cases, a process which is incompatible with vision, and which never, under any circumstances, takes place. This appears to be an admirable arrangement, for if the retina were so exquisitely sensitive, as is commonly supposed, vision must cease when there is a very brilliant light. As it is, this portion of the animal economy has been wisely contrived, so that the sensitive part of the eye may be defended from an irritating supply of light, whilst the retina may remain exposed in order to effect its function, as in the instance alluded to, which is only a more permanent mode of effecting the same end, and that without having recourse to the long-continued, voluntary contraction of the eye-lids. Does it not, indeed, continually happen to every one to be so circumstanced that he is compelled almost to close the lids, and thus protect every part of the eye, except the pupil and retina, as when walking in a cloud of dust, or surveying any highly illuminated object?

From all these facts it appears, then, to be indisputable, that sensibility to light may exist without vision; that they are two distinct properties, possessed by different portions of the eye; and that the sensibility to light exists in the exterior of the organ and the iris, and is derived from the fifth nerve, whilst vision is the function of the retina, through the optic nerve.

In a former chapter we have already treated at great length upon the subject of the iris; and therefore the question, whether it acts independently of the retina or otherwise, must now be disposed of somewhat briefly. All authors state that the iris is placed before the retina, as a means of defending it from an undue supply of light, which they presume it could not bear, because of its exquisite sensibility to that agent. I have before endeavoured to show that the varying quantity of light which is admitted into the interior of the eye, by means of the varying dimensions of the pupil, has reference to the illumination of the picture formed on the retina, rather than to the sensibility of that membrane to the stimulus of light. I have endeavoured, moreover, to prove that this sensibility is not a function of the retina, but of the eye generally.

Several facts may be adduced in proof of the position that the motions of the iris are independent of the retina. First, there is no direct communication between them, as there is between a muscular organ and the nerve which excites it, as there is between the iris and the ciliary nerves, which are the proper nerves of that structure. Farther, innumerable cases occur in which the retina is completely paralyzed, and yet the actions of the iris are as perfect as ever; and the iris is likewise very often in the same condition, when the retina is perfectly healthy. In the state of sleep, too, the pupil is firmly contracted, a condition in which the retina is inactive, so that the most powerful action of the iris takes place when no light arrives at the retina. In cases of cataract, where the pupil is completely blocked up by an opaque, solid body, so that very little light can pass through it, we nevertheless find the pupil contracting and dilating as regularly as ever. Here the exterior of the eye and the iris are fully exposed to the light, and the consequence is the healthy action of the pupil; whilst it is clear that if that action depended upon the light influencing the retina, the pupil must be nearly or altogether inactive, or indeed widely dilated, as in the eye of a person when in a dark room.

Mr. Wardrop, in his "Morbid Anatomy of the Human Eye," seems to have inclined to a similar view in the following paragraph:—"Perhaps the motions of the iris may have some analogy to those motions in plants produced by the influence of the sun's rays. Its motions in an eye where there is a complete cataract, or where the aperture of the pupil is drawn aside from a part of the cornea which has become opaque till it gets opposite to a transparent portion, makes this opinion probable."

The fair and reasonable inference to be deduced from these facts appears to be, that the exterior of the eye and the iris are acted upon by the light, and that the contraction of the pupil is the result of that action, and consequently that the latter is not influenced by the quantity of light sent to the retina. And here we perceive a precise agreement between the degree of sensibility of the eye to light and the regulation of the proper supply of it to the interior of the organ,—to the retina,—for the purposes of accurate vision; for an excess of light is equally disagreeable to the sensitive condition of the eye, as it is detrimental to perfect vision; and, on the other hand, a feeble supply of light, by permitting the dilatation of the pupil, is favourable to the vision of objects in that condition. And these changes usually take place without the interference of the will, nay, without our knowledge; so nicely is every action ordered which is essential to the well-being of the individual. Thus during the state of sleep, and when under the influence of a powerful stimulus, such as light undoubtedly is to the fine and delicate structures of which the eye is formed, it is necessary that they should be protected. In sleep, particularly, it is necessary that no external impressions from light,—whether regarded simply as a stimulus, or as a mean by which images are to be formed on the retina,—should be intruded through this organ to the sensorium. And all this is accomplished by the sphincters of the eye-lids and of the iris, by laws which admit of no interruption, and which are exercised independently of the will, so as to be effected for us whether we are desirous of it or not, and whether we are agreeable or otherwise that it should be so.

Whilst we are in the state of sleep, it is manifest that we are in a condition perfectly unsuited to the proper use of the organ; accordingly, on waking, the eye-lids immediately fly open, and the pupil expands; and thus we see the necessity for their possessing this power of contracting and widening their apertures. For, as with the eye-lids, so with the iris, if either were to remain closed when we awake, we should not see. This, however, with the latter does not hold to such an extent as with the former; but still if the pupil were to remain contracted as in sleep, the effect would be that, in a feeble light, little or nothing would be seen, since we find that it always dilates itself when in a dark situation. That it possesses the property of contracting and expanding itself to every possible extent, shows that it is admirably adapted to allow of as much or as little light to pass into the eye as is suitable to the purposes of accurate vision, in every possible circumstance.

Two statements, which seem opposed to the views we have inculcated, must here be noticed. The first is this. FONTANA, an Italian author of note, made an experiment which consisted of directing a pencil of light upon the iris. It is affirmed that, so long as it was directed simply upon the iris, no action was produced, but that when he allowed it to enter the pupil, so as to get to the retina, a contraction of that aperture followed. I imagine there must be some fallacy about this experiment.

The sphincter of the iris being the part that contracts, so as to diminish its aperture, it is difficult to conceive that a pencil of light could be transmitted to the retina without its striking the pupillary margin; and, if it did that, it would readily account for the contraction. I consider such an experiment quite inconclusive, and as opposed to what is observed in cases of cataract, where the light can only strike upon the exterior of the eye and the iris.

The second opposing statement which has been alluded to is the grave assertion, that if the iris be touched or pricked it is not sensible. Now this I know, that in operations for cataract nothing is more common than to find the pupil contracting itself to the utmost, and sometimes to such a degree as to be exceedingly inconvenient. This I have witnessed in very many instances; and when it does not take place, it is probably because the iris has been previously paralyzed by the application of belladonna.

In addition to the sensibility of the eye to light, we know that it is very sensible likewise to the contact of bodies or touch. It is peculiarly so; for very slight matters getting upon its surface are productive of excessive irritation, which falling on the skin would not be perceptible. In an instant, the muscular apparatus of the eye is put in motion to extrude the irritating body. The hydraulic apparatus is likewise excited, and a shower of tears is immediately forced upon the surface of the eye for the purpose of washing off the source of irritation. The amount of irritation depends upon the situation of the offending body; for if a particle of dirt lodge upon the eye in such a position that the eyelids do not cover it, then very little uneasiness is felt; but if it be placed between the two, on either the surface of the eye or of the lid, the forcible contraction of the latter upon the former gives excruciating pain, which is always aggravated by the winking motions of the lids, and relieved by keeping them at rest and taking off the pressure from the surface of the eye. This sensibility of the surface seems to have a special reference to these more minute bodies, for in manipulating the eye, as is done without ceremony by the surgeon in his operations, considerable pressure is made upon it without any uneasiness resulting. Hence some persons, particularly oculists, laugh at the idea of the eye being a remarkably sensitive organ, and always act upon the contrary supposition; for the eye is scarcely more sensitive to a wound than is the general surface of the body.

This special sensibility is designed for its protection, since if these irritating matters were to remain in contact with the eye, inflammation, and opacity, and loss of vision, would inevitably result. This property being received through the influence of the fifth nerve, if it becomes paralyzed, these evils usually result, and because the eye, in that condition, is insensible to the presence of irritating substances, the mischief imperceptibly advances. Thus, in the experiments related by Majendie, of division of this nerve, the eye was rendered insensible, inflamed, opaque, and finally became sloughy, and disappeared. And this shows the great importance of the proper sensibility of the surface of the eye to its due and healthy action, and is another addition to the list of proofs of the unbounded care and munificence with which our every want has been provided for by the Dispenser of all good.

CONCLUSION.

We are told of a great philosopher who, when asked for proofs of a Deity, picked up a straw and proceeded to demonstrate from it the existence of a Great First Cause.

If so much could be demonstrated from so apparently trivial a substance, we surely cannot hesitate to admit, with Paley, that "were there no example in the world of contrivance except that of the eye, it would be alone sufficient to support the conclusion which we draw from it, as to the necessity of an intelligent Creator."

In the preceding pages we have accumulated fact upon fact, and evidence upon evidence, in support of this important truth. We have seen contrivance displayed more especially in the adaptation of the eye to light, and of the properties of the latter to the former; we have witnessed it in the construction and arrangement of the lenses, so as to produce images of objects; we have traced it in the structure of the coats of the eye, one transparent, the other rendered carefully opaque, both equally firm and capable of protecting the delicate textures which they surround; we have observed it in the dark pigment spread out upon a fine membrane lining the inner surface of the eye-ball, for the express purpose of absorbing superfluous light, thereby insuring the distinct representation of images; it has been rendered apparent in the septum placed across the chamber of the eye, endowed with a power of expanding and contracting its aperture, according to the varying intensity of light and shade; and it has been equally manifest in the placing the expanded nerve of sense in the precise part of the eye where the images are formed, to be thence conveyed to the brain, the centre of intelligence. Not less striking has been the evidence of design in the various subsidiary structures than in those more immediately connected with vision: we have noticed it in the arrangement, complicated and intricate as they are, of the muscles and nerves of the eye-ball; in the relation between the form and position of the orbit and of the eye and its appendages; in the structure and offices of the eye-lids; in the series of glands, ducts, and tubes, connected with the hydraulic apparatus; and lastly, in the refined sensibility of the organ to external impressions.

After the enumeration, in detail, of so many unequivocal instances of skilful contrivance and of exact agreement in so many parts, differing in form, structure, and situation, it must be superfluous to enter into a formal argument to show that all these could not have been constructed and arranged without the intervention of an intelligent Being, capable of perceiving the relation necessary to be established between them, and of skilfully adapting them to each other. Such a proposition is, indeed, self-evident; for, as there is no known example of an instrument, formed in accordance with optical principles and capable of producing images, having been originated by accident; so the eye, an optical instrument of surpassing beauty and skill, formed on unerring principles, and producing the most finished pictures, could not have been originated otherwise than by the agency of a being possessed of a knowledge of those principles, and capable of applying them to the mechanism of this organ. As nothing, therefore, can be more evident than the inimitable, unapproachable perfection of the eye;

so, likewise, it is equally evident, that the Great Being who fashioned it and endowed it with its wondrous powers, for the good of his creatures, is of an infinite and unapproachable excellence in point of intelligence, power, and beneficence.

INDEX.

ALBINO, eye of, 128, 277
Aqua Morgagnii, 72, 79
Aqueous humor, 29, 51, 74
Arnott, Dr., on light, 96

Bell, Sir C., on the eye-lids, 248
——— condition of the eye in sleep, 236
——— searching motion of the eye, 207
——— muscles and nerves of the eye-ball, 234
——— sensibility of the retina, 263
——— undulatory theory, 104
——— varying density of the humors, 77
Birds, eye of, 53, 56, 63, 67, 119, 131, 257, 258
Blind individuals of note, 4, 5, 6
Blindness, Milton on, 2, 3
Brewster, Sir D., on absorption of light, 103
——— colours, 102
——— the crystalline lens, 59
——— the optic nerve, 190

Camera obscura, invention of, 50
Caruncula lacrymalis, 253
Carus on the iris, 145. 169
Cataract, its nature, 35, 70
Cheselden's case, illustrative of vision, 9
Choroid membrane, 121
Chromatic aberration, 28, 93
Cilia, or eye-lashes, 39, 251
Ciliary body, 132
——— nerves, 133, 170
——— processes, 34, 134
——— vessels, 130

Ciliary zone, 135
Colours, beauty and utility of, 104
——, Dr. Prout on, 102, 104
—— of the iris, 145, 156
Conjunctiva, 254
Contracted pupil, effects of, 154
Cooper, Mr. B., on the sixth nerve, 229
Cornea, transparent, 32, 109
——, conical, 66
Crystalline lens or humor, 29, 51
——, capsule of, 72
——, chemical composition of, 72
——, muscles and tendons of, 60
—— of birds, 53
—— of fishes, 52
Cuttle-fish, iris of, 144

Dalrymple on the ciliary vessels, 130
Design, more prominent proofs of, 26, 32
Diaphragm of the telescope, 148
Dolland's improvement of optical instruments, 29

Edwards, Dr., on the physical effects of light, 271
Elliotson, Dr., on the sensibility of the retina, 266
Eye, adjustment of, 26, 59, 61, 132, 137, 153
——, appendages of, 37, 204, 239
——, coats of, 107
——, defences of, 239
——, form of, 25
——, humors or lenses of, 29, 35, 48
——, muscles of, 42, 211
——, nerves of, 44, 133, 170, 188, 219, 277
——, nutrient apparatus of, 45
——, sensibility of, 263
——, superior construction of, 26
——, proofs of design in, 26, 32
Eye-brows, 261
Eye-lashes, 39, 251
Eye-lids, 37, 244
——, muscles of, 37, 246
——, effects of paralysis of, 38

Far-sightedness, 64
Feeling, insufficiency of, in acquiring knowledge, 19
Fishes, eye of, 52, 116, 127, 144, 257
Foramen centrale, 199

Glands of the eye, 253
———, Harderian, 257
———, lacrymal, 40, 254
———, Meibomian, 253
Glass, discovery of, 49
Grant, Dr., on sensibility to light, 268

Haw of quadrupeds, 259
Herschell, Sir John, on the camera obscura, 50
———————, on light, 100
———————, object glass of, 94
Holman, Lieutenant, the blind traveller, 5
Huber, M., the blind naturalist, 4
Humors of the eye, 29, 34, 51
Huyghens, his theory of light, 98
Hyaloid membrane, 74

Images of objects, how produced, 20
——————— inverted on the retina, 18, 91
Iridian ligament, 133
Iris, action and uses of, 33, 139
——, antagonist fibres of, 161, 181
——, colour of, 145, 156
——, correspondence of, with the eye-lids, 163
—— of cuttle-fish, 144
—— of fishes, 144
——, Fontana's experiments on, 286
——, independent action of, 283
——, mobility of, 145
——, nerves of, 133, 171
——, sensibility of, 281
——, voluntary power over, 177

Kepler's discovery of the uses of the various parts of the eye, 50
Kidd, Dr., on sleep and darkness, 273

Lacrymal apparatus, 40, 254
Lawrence on the oblique muscles, 228
Lenses, various kinds of, 88
Lenticular ganglion, 170
Light, absorption of, 103, 122
——, Arnott on, 96
——, chemical action of, 124
——, nature and properties of, 95
——, physical effects of, 271
——, refraction of, 85
——, sensibility to, 263

Majendie on adaptation of the eye, 27
——, experiments on the nerves by, 167, 277
—— on the sensibility of the retina, 264
Marsupium of birds, 131
Mayo on the third nerve, 168
Metcalf, John, celebrated blind person, 6
Milligan, Dr., on adjustment, 27
Milton on the loss of vision, 2, 3
Molluscous animals, eye of, 118
Muscles of the eye-lids, 37, 246
—— —— eye-ball, 42, 204, 211
—— —— third eye-lid, 258
—— —— haw, 259
Muscularity of the iris, 160

"Napoleon Empereur" on the iris, 158
Nasal duct, 41, 256
Near-sightedness, 65, 152
Nerves of the eye, 44, 133, 170, 188, 219, 277
Newton, Sir Isaac, on light, 98
Nictitating membrane, 258

Ophthalmic ganglion, 170
Optic nerve, 188, 200
Optical instruments, origin of, 48
Orbit, its situation and use, 240

Paley on the sensibility of the retina, 265
—— —— foramen centrale, 198

Pallas on the perfection of sight in men, 68
Pecten of birds, 131
Pigment of the eye, 33, 122
Porta Baptista, discoverer of the camera obscura, 50
Prismatic or solar spectrum, 101
Prout, Dr., on colours, 102, 104
Pulley of the superior oblique muscle, 213
Pupil, 146
——, varying shape of, 146, 155
——, state of in sleep, 164
Pupillary membrane, 146

Quadrupeds, eye of, 53, 127, 145, 155, 259

Retina, structure and use of, 36, 188, 200
——, sensibility of, 264
Roget, Dr., on voluntary action of the iris, 177

Saunderson, the blind professor, 5
Sclerotic coat, structure and use of, 111
——————, density of in fishes, 116
Sensibility of the eye, 263
—————— retina, 264
Shakspeare on the acquirement of vision, 8
Shaw, Mr. John, on the voluntary action of the iris, 178
Sneezing produced by light, 279
Spherical aberration, 28, 92, 149
Swan, Mr., on the fifth nerve, 173
Swift's definition of vision, 8

Tapetum, 128
Tarsus or cartilage of the eye-lid, 251
Tears, formation of, 40
Third eye-lid of birds, 258
Trochlea or pulley, 213
Trochlearis muscle, 213

Undulatory theory of light, 97
Uvea, 143

Vasa vorticosa, 130

Vision, loss of, 2
———, nature of, 8, 193
———, difficulty of acquiring, 14
———, distinction between and sensibility to light, 275
———, excellence of, in uncivilized man, 68
———, how produced, 16
Vitreous humor, 29, 51, 73

Wardrop, Mr., interesting case by, 11
—————, on the action of the iris, 284

Young, Dr., on the crystalline lens, 59
——————— undulatory theory, 98

Zinn, zone of, 135
Zone, ciliary, 135

THE END.

Printed by W. Clowes and Sons, Stamford Street.

131
361
2

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

BioMed